Dissertation on

RADIOLOGICAL AND SURGICAL ORIENTED ANATOMICAL STUDY OF "VARIATIONS IN EXTRAHEPATIC BILIARY DUCTAL SYSTEM AND ITS RELATED VESSELS" WITH ITS CLINICAL IMPLICATIONS

Submitted in partial fulfillment for

M.S. DEGREE EXAMINATION

BRANCH - V ANATOMY

upgraded Institute of Anatomy

Madras Medical College & Research Institute, Chennai

THE TAMIL NADU Dr.M.G.R. MEDICAL UNIVERSITY
CHENNAI - 600 003.
TAMIL NADU

SEPTEMBER - 2006

CERTIFICATE

This is to certify that the dissertation on **RADIOLOGICAL AND SURGICAL ORIENTED ANATOMICAL STUDY OF "VARIATIONS IN EXTRAHEPATIC BILIARY DUCTAL SYSTEM AND ITS RELATED VESSELS" WITH ITS CLINICAL IMPLICATIONS** is a bonafide work, carried out in the upgraded Institute of Anatomy, Madras Medical College, Chennai - 600 003, during 2003 - 2006 by **Dr.A.SHARMILA**, under my supervision and guidance in partial fulfillment of the regulation laid down by the Tamil Nadu Dr.M.G.R.Medical University, for the M.S., Anatomy, Branch - V Degree Examination to be held in September 2006.

DEAN
Madras Medical College
Chennai - 600 003.

Prof. Dr. CHRSTILDA FELICIA JEBAKANI, M.S.,
Director & Professor,
Upgraded Institute of Anatomy,
Madras Medical College,
Chennai - 600 003.

Date :

Station :

Date :

Station :

CONTENTS

ACKNOWLEDGEMENT

I must express my sincere thanks and indebtedness to my respected teacher and guide **Dr.CHRISTILDA FELICIA JEBAKANI, M.S.,** Director and Professor, upgraded Institute of Anatomy, Madras Medical College, Chennai, who has only motivated me to conduct this study and provided all the guidance and facilities available in the entire institution to my study.

I sincerely thank **Dr.KALAVATHI PONNIRAIVAN, B.Sc., M.D.,** Dean, Madras Medical College, Chennai for Permitting me to avail the facilities in the institution for my study.

My deepest gratitude to **Dr.VALLINAYAKAM, M.D.,** Director and Professor, Institute of Forensic Medicine, Madras Medical College, Chennai for permitting me to collect the specimens and **Dr.PANNERSELVAM, M.D.,** who helped me for collection of specimens.

I sincerely thank **Dr.V.MADHINI, D.G.O., M.D.O.G.,** Director and Superintendent, Institute of Obstetrics and Gynecology, Egmore, Chennai for helping in foetal study.

My thanks and gratitude to **Dr.SWAMINATHAN, M.D.R.D.,** Bernaurd Institute of Radiology, Madras Medical College, Chennai for his help in radiological study, and **Dr.SUNDARESAN, D.M.R.D.,** for his help in taking Radiological Pictures.

My deepest gratitude to **Dr.SRIKUMARI DHAMODHARAN, M.S., M.Ch.,** Department of Surgical Gastroenterology, Madras Medical College, Chennai for her kind help in my clinical study.

I sincerely thank **Dr.I.JAYARAJ,** D.L.O., M.S., **Tmt.M.S.THENMOZHI, Dr.B.CHEZHIAN,** **M.S.,** Assistant Professors, Institute of Anatomy and **Dr.N.M.PICKTHAL,** **M.S.,** **Dr.TAMILSELVAN,** **M.S.,** Tutors, Institute of Anatomy, Madras Medical College, Chennai for their valuable support.

I express my thanks and endearment to **Dr.R.ARUNKUMAR, M.D.,** for his help throughout this study.

I am also thankful to **Dr.P.VIMALNATH, D.M.R.D., (DNB)., and Dr.T.DINESH KUMAR, M.D., M.R.C.P.,** for helping me in Radiological study and journal collection.

I also thank my Seniors **Dr.G.AMUDHA, M.S., Dr.K.SUBA ANANTHI, M.S., Dr.M.SUDHAKAR MADAVAN, D.L.O.M.S.,** for their valuable advice, my colleagues **Dr.S.SUMATHILATHA, D.G.O.,** for her constant support, **Dr.V.SATHYALAKSHMI, Dr.KAVIMANI, Dr.IVAN JAMES PRATHEESH KUMAR, Dr.VIJAYALAKSHMI, D.G.O.,** to my juniors **Dr.PREETHYSAM, Dr.JAYANTHI GNANADEEPAM, Dr.M.JAYANTHI and Dr.ANITHA,** for their kind co-operation.

I am thankful to **Mr.JABBAR** for helping me in preservation of the specimens and **Mr.SUGENDRAN,** for collecting the specimens.

I am grateful to my beloved Parents **Mr.D.APPADURAI, M.Com., Mrs.A.SARASWATHI,** my husband **Dr.A.ARISTOTLE PLATO, D.Ch., M.R.C.P.Ch,** my sister **Er.A.NANDHINI,** and all my family members who made this study a reality.

AIM OF STUDY

"Technically Gall bladder surgery is much the most difficult of the any abdominal surgery and inadequate appreciation of the abnormalities of this region doesn't lessen the risk"

- E.R. Flint -

In no regions of the human body are anomalies so common as in the biliary ducts and its adjacent blood vessels. In analysis of the literatures, many investigations have been carried out about the variational anatomy of biliary apparatus, because of the post operative traumatic defect of the biliary system, despite much improvement in surgical skills.

The importance of the variational anatomy of the extra hepatic duct system and its related vessels, in operative and invasive procedures, was first predicted by "Schachner" (1916).

Variation is "rampant" (constant) and is impossible to present any one pattern as normal.

Abnormalities of the major ducts and accessory hepatic ducts during cholecystectomy is the most frequent cause for post operative complications such as leakage of bile, fistula, necrosis of liver and hepatic failure. Biliary peritonitis leads to more serious trouble, if unrecognized during surgery.

Similarly, arterial variations give rise to frequent haemorrhage during surgery. They may lead to injuries to ducts, as during the process of clamping the anomalous vessels, ducts can also be included in the ligature along with the artery. More over, recognition of structures in the calot's triangle is considered to be important to minimize injuries of bile ducts and their related vessels.

Narrow exposure and variational anatomy are the two major things that contribute to operative difficulties to the surgeons.

It is like wise true, that anatomical knowledge is critical to prevention of injuries of the structures in hepatoduodenal ligament for interpretation of cholangiograms like **Percutaneous Transhepatic Cholangiography (PTCA), Endoscopic Retrograde Cholangio pancreatography (ERCP)** and **Magnetic Resonance Cholangio Pancreatographic (MRCP)** procedures.

Hence preoperative, post operative or peroperative procedures whether open cholecystectomy or laparoscopic cholecystectomy, it is necessary to correlate gross anatomy with radiological studies.

Since the importance of variations in the extrahepatic biliary ductal system and calot's triangle has been much observed by the surgical gastro enterologists, radiologists and general surgeons,

So was the study of the ductal system and its related arterial vessels in the hepatoduodenal ligament, on the following parameters, carried out.

I. Formation of common hepatic duct

Site of union of right and left hepatic ducts

II. A) Types of union of cystic duct with common hepatic duct

B) Level of termination of cystic duct with common hepatic duct

III. Length of the individual ducts

IV. Course and arrangement of structures in hepatoduodenal ligament

V. Variations in ductal system

VI. Variations in arterial system related to duct system

VII. Calot's triangle

Description of individual parameters

I. Formation of common hepatic duct

Site of union of right and left hepatic ducts

a. extra hepatic union of right and left hepatic ducts

b. intra hepatic union of right and left hepatic ducts

II. A. Types of union of cystic duct with common hepatic duct

a. angular

b. parallel

c. spiral

B. Level of termination of cystic duct with common hepatic duct

a. high level

b. low level

c. normal level

III. Length of the individual ducts.

a. cystic duct

b. common hepatic duct

c. common bile duct

d. any accessory duct, if present

IV. Course and arrangement of structures in hepatoduodenal ligament

V. Variations in ductal system

a. presence of any accessory hepatic or cystic ducts

b. mode of termination of accessory hepatic or cystic ducts, if present

VI. Variations in arterial system related to duct system

a. cystic artery

i. origin

ii. its relationship to common hepatic duct

b. right hepatic artery

i. origin

ii. its relationship to common hepatic duct

VII. Calot's triangle

a. boundaries

b. contents

EMBRYOLOGY

The hepatic rudiment first appears on the 18th day in the 7th somite embryo. In the 19th somite embryo, it can be recognised in transverse section as a `T', shaped diverticulum of the endoderm from the convexity of the future duodenal loop.

The diverticulum projects ventrally and cranially into the surrounding mesoderm of the septum transversum. The hepatic diverticulum will eventually give rise to the endodermal portion (future parenchyma) of the liver and the epithelium of the biliary apparatus.

By the 23rd - 25th somite stage, the hepatic diverticulum enlarges and a localized proliferation of endodermal cells which appears as a bulge on its ventrocaudal surface results in the division of the diverticulum into a large cranial portion `pars hepatica' and a small caudal portion `pars cystica'. The pars cystica gives rise to gall bladder and cysticduct. The pars hepatica grows cranically away from the pars cystica and gives rise to the parenchymal elements of the liver, the intrahepatic ducts and the right and left hepatic ducts. That part of the original pars hepatica adjacent to the pars cystica becomes the common hepatic duct.

The thick walled pars hepatica sends out proliferations of endodermal cells in the form of solid hepatic cords into the adjacent mesenchyme of the septum transversum. These cords anastomose around and isolate either small clusters of the mesenchymal cells of the septum transversum or small preformed vesicles in this mesenchyme.

As the hepatic cord continue to grow and anastomose, the isolated vesicles containing blood cells becomes confluent to form continuous channels which become small blood vessels.

With the increased proliferation of the hepatic parenchyma, there is an increase in the size and length of the gall bladder, cysticduct and commonbileduct.

According to **Patten** these cords grow out between the layers of splanchnic mesoderm and become tubules, the distal portions of which form the secretory tubules of liver and proximally these tubules become confluent and in a tree like fashion they taper down to form the hepatic ducts, common hepatic duct and common bile duct. Many of these tubules disappear or colaesce and leading to multiple variations in the limbs of the tree due to the manner of their emergence or failure of disappearance. The latter would give rise to various accessory ducts[1].

At about the 46th day, the mesoderm around the extrahepatic ducts begins to migrate into the liver along the major branches of the portalvein. As this mesoderm accumulates round the portalvessels the adjacent paraenchymal cells develop into duct epithelium. The migration of the mesoderm and the transformation of adjacent parenchymal cells of the tubules into typical epithelial duct cells (ducts) progress from the hilum of liver.

Peripherally, where there is little or no developing connective tissue, there is an abrupt change between the duct cells and the parenchymal cells although the two cell types are continuous. This abrupt transition is found in adult, between the bile canaliculi and intrahepatic ducts[2].

REVIEW OF LITERATURE

Galen (130-200 AD), stated that humans have a single bile duct, or paired bile ducts.[3]

Von Wyss (1870), was the first to state about the variations in the formation of common bile duct.[3]

Brewer, in 1900, from dissection of 50 specimens observed that extrahepatic union of right and left hepatic duct in 100%, intrahepatic union of right and left hepatic duct in 0% and presence of a single accessory hepatic duct in 0.5%.[4]

Rugg Ernst et. al., (1908), in their study of 43 cadavers, showed the various types of union of cystic duct with common hepatic duct. Cystic duct joined the common hepatic duct, by making a sharp angle in 35% and it ran parallel with the common hepatic duct for a variable distance in 20%, the two may be so closely bound to make their separation difficult. This type was also described by 'Delbet' as *"canal double hapato – kystique"*. Cystic duct ran a spiral course and joined the hepatic duct on its left side in 45%.

He also found that extrahepatic union of right & left hepatic ducts in 79% (34) cases and intrahepatic union in 20.9% (9) cases.[5]

Schachner (1916), from a study of 76 cases, described about 8 anomalies of extrahepatic biliary duct system, in which double cystic duct was present in 2 cases, anomalous hepatic duct in 5 cases and absence of common duct (infant) in one case.[6]

Reich (1918), produced first roentgenography of biliary tree, by injecting bismuth paste and petrolatum into an external fistula.[3]

Eisendrath (1918), in his study on 100 specimens, showed the types of union of cystic duct with common hepatic duct. In that, angular type of union was observed in 75 cases, parallel type of union in 17 cases, and spiral type in 8 cases.

He also described that extrahepatic union of right and left hepatic ducts in 100%, intrahepatic union in 0% and the frequency of occurrence of accessory ducts was 0% in his study.

Regarding the relationship of cystic artery with common hepatic duct, in 27 cases the cystic artery crosses ventral to common hepatic duct, and in 73 cases the cystic artery crosses dorsal to common hepatic duct.[7]

E.R.Flint (1922-23), in his work on 200 subjects, discussed about origin, course of right hepatic artery and cystic artery. The various origins of right hepatic artery, given by him are as follows:

- From main hepatic artery in 158 cases
- From superior mesenteric artery in 42 cases
- Presence of two right hepatic arteries in 7 cases. (One arising from hepatic proper, other from superior mesenteric artery)
- In other two cases, the right hepatic artery arises from hepatic artery proper itself

He described about the course of right hepatic artery, in relation to the common hepatic duct.

- Behind the common hepatic duct in 136 cases
- Front of the common hepatic duct in 25 cases

He stated that right hepatic artery, when it passes behind the common hepatic duct, low down near the junction of the cystic duct, is more liable to injury during cholecystectomy.

About the origin of the cystic artery, he says

- From the right hepatic artery in 196 cases
- From left hepatic artery in 3 cases
- From gastro duodenal artery in 1 case

Regarding the course of cystic artery to common hepatic duct, it passes in front of the common hepatic duct in 32 cases and passes behind it in 168 cases (to the right side of common hepatic duct).

In his study, he noted the accessory cystic artery in 31 cases, out of which it arises from right hepatic artery in 16 cases, from left hepatic artery in 3 cases, from gastro duodenal artery in 11 cases and from superior pancreatico duodenal artery in 1 case.

Ignorance of the occurrence of accessory cystic artery is responsible for severe hemorrhage.

Diagram illustrating various abnormalities in the arteries and Bileducts met with in gallbladder surgery as shown by flint is given in Pic.(1).

His study on the ductal system shows, presence of 29 accessory bile ducts. All were accessory right hepatic ducts, joins the extrahepatic ducts, any where between the point of the junction of right and left hepatic ducts and the point at which the cystic duct opens into the main duct.

He also classified the accessory ducts into 3 types, according to the level at which they enter the main duct.

1. The junction occurs in the upper half of the common hepatic duct or in the right hepatic duct (high level of union) in 9 cases.

2. The junction occurs in the lower half of the common hepatic duct. the union is so near that of the cystic and common hepatic ducts in 9 cases.

3. The junction is at the union of cystic and common hepatic ducts. The junction is usually in the actual angle of the cystic and common hepatic ducts, but may be in the extreme lower end of the common hepatic duct or in cystic duct in 10 cases.

In one specimen, it leaves the right hepatic duct and enters the cystic duct.[8]

Mcwhorter in 1923, by dissecting 37 cadavers found the frequency of occurrence of accessory bile ducts as 1 percent.[9]

Beaver in 1929, dissected 5 accessory bile ducts (9%) from 57 specimens.[10]

Thompson dissected 50 specimens during 1933, and stated that extrahepatic union of right and left hepatic ducts in 90% and intrahepatic union of right and left hepatic ducts in 10%. The union of cystic with common hepatic duct was angular in 45 cases, parallel in 3 cases and spiral in 2 cases.[11]

Henry Gray in 1936, observed the following variations in the extrahepatic ducts and its related arterial systems.

1. cystic duct occasionally joins the right hepatic duct.
2. cystic artery passes behind or in front of the common hepatic duct.
3. accessory hepatic ducts are more common from the right lobe of the liver.
4. accessory cystic artery may arise from the common hepatic artery.[12]

A. Lurje M.D. (1937) studied elaborately on the extrahepatic bilary passage by dissecting 194 cadavers. They classified the union of cystic duct with common hepatic duct as follows Pic.2.

Cystic duct joined hepatic duct at acute angle in 46.9% of cases Pic.2a.

Cystic duct followed the right border of the hepatic duct for some distance before entering it in 30.9% of cases, Pic.2b

Cystic duct made a spiral course behind the hepatic duct and entered it on its left anterolateral surface in 6.7% of cases, Pic.2c.

Cystic duct made a spiral course and followed the posterior surface of hepatic duct for some distance and entered it posteriorly in 15.5% of cases, Pic.2d.

Regarding the supernumerary bile ducts, the supplementary bile duct was noted 22 times (11.3%). In 1.6% the cystic duct entered the point of confluence of the hepatic duct with accessory duct. The cystic duct passed the right and left hepatic ducts and joined them at a common point, to form a single hepatic duct. In 2.8%, large and small biliary passages emerged from the right lobe of liver, entered the cystic duct. These accessory passages may be the cause of post operative biliary fistulae.[13]

S.Dana Weeder, M.D., and Doctor Swartley (1939), reported a case of choledochus cyst with double common bile duct, in which the right and left hepatic ducts were separate and did not join as normal. They proceeded separately to duodenum.[14]

Clyde Everett, M.D., and Harold E Machumber M.D., in 1942, described about anomalous distribution of extrahepatic biliary ducts, from a case report of 'Barium' study of a white female, in which gall bladder can not be visualized.

In the same case, during autopsy they found that a single hepatic duct emerging from each of the two lateral lobes of liver. These joined immediately to form a single main hepatic duct, 4 cm from hilum of liver divided into 2 branches. One branch emptied into the 2nd part of duodenum at ampulla of vater and the other branch emptied into the posterosuperior aspect of the lesser curvature of stomach, 1 cm proximal to pyloric ring.[15]

Paul Campiche, M.D., in 1944, from a surgical case during cholecystectomy, described about an anteduodenal position of the cystic duct in which cystic duct passed in front of duodenum.[16]

Edward H Daseler M.D., et al., (1947), from a study of 500 specimens stated about the various origins of right hepatic artery, Pic.3.

A normal right hepatic artery, originating from a normal common hepatic artery was present in 83.2% (416/500) of cases.

A replacing type of right hepatic artery is one by which the right lobe is supplied from some other source, was present in 16.8% (84) of cases. In that,

in 11.2% (56) the replacing right hepatic artery originated from superior mesenteric artery.

in 0.2% (1) from aorta.

in 4.4% (22 cases), the right hepatic branch of common hepatic artery was derived from superior mesenteric artery.

in 0.2%, the common hepatic artery arose directly from aorta.

in 0.8% (4 cases), the right hepatic artery arose as a direct branch of the coeliac axis.

Accessory right hepatic arteries in addition to a normal or replacing arteries occurred in 7.2% (36 cases). Among that,

in 3%(15 cases) it arose as a branch of superior mesenteric artery.

in 2.6% (13 cases), as a branch of left hepatic artery.

in 1% (5 cases), from the gastroduodenal artery.

in 0.4% (2 cases), from the coeliac axis.

in 0.2% (1 case), directly from aorta.

Regarding the relationship of right hepatic artery with duct system, in 65% (325) cases the artery crossed posterior to the common hepatic duct.

in 11.6% (58) cases, it crossed anterior to common hepatic duct.

in 3.6% (18) cases, it crossed posterior to right & left hepatic ducts.

in 0.8% (4) cases, it crossed anterior to right & left hepatic ducts.

in 11.6% (5) cases it crossed posterior to common bile duct.

in 1.4% (7) cases it crossed anterior to common bile duct.

in 4.4% (22) cases it crossed entirely to the right of common bile duct and hepatic ducts.

in 1.6 (8) cases entirely to the left of common bile duct and hepatic ducts.

in 11.4% (57) cases the artery crossed posterior to cystic duct.

in 0.8% (4) cases it crossed anterior to cystic duct.

Regarding the various origins of cystic artery, he classified it into 12 distinct types as follows, Pic.3a.

Type I : commonest arrangement in which, hepatic artery of coeliac origin divides to supply right and left hepatic lobes. The gall bladder receives its cystic branch from nearer or right division. This is encountered in 58.6% (340 of 580 cystic arteries).

Type II : cystic artery arises from the proximal portion of the right hepatic artery. This arrangement occurred in 13.1% (76/580) of cases.

Type III : cystic artery originates from an aberrant right hepatic artery, derived from superior mesenteric artery. This pattern occurred in 11.9% (69/580) of cases.

In another 4.2% (21) cases, it was not the right hepatic but common hepatic artery took origin from superior mesenteric artery.

Type IV: cystic artery derived from left hepatic artery in 6.2% (36/580)

Type V: cystic artery arose as a branch of common hepatic artery in 2.8% (16/580).

Type VI: cystic artery arose from gastroduodenal artery in 2.6% (15/580).

Type VII: In 0.4% (2) cases cystic artery arose as a branch of coeliac axis.

Type VIII: In 0.6% (3) cases it was derived from a replacing or from an accessory type of right hepatic artery. The later was derived inturn from a source other than superior mesenteric artery.

Type IX: In 0.2% (1) case the sole source of arterial supply to gall bladder was a long, slender cystic artery derived from first portion of superior mesenteric artery.

Type X: In 0.2% (1) case from superior pancreatico duodenal.

Type XI: Lipschutz has reported 2 cases in which cystic artery originated as a direct branch from aorta. This unusual origin was not encountered in the present series.

Type XII: A single case has been reported by Kosinski in which cystic artery arising from a branch of right gastroepiploic artery. No such cases were encountered in the present series.

Regarding double arteries he showed 15.6% (78/500) of cases, the course of the dual cystic arteries are most commonly derived from right hepatic artery. However branches from left hepatic, common hepatic and from the gastroduodenal arteries also occur in a decreasing order of frequency.

Regarding accessory cystic arteries he encountered it in 11.26% (65) specimens.

in 77% (50/65 specimens), it arose as a branch of a normal right hepatic artery.

in 9.2% (6) cases as a branch of gastroduodenal.

in 6.25% (4) cases from common hepatic artery.

in 4.7% (3) cases from left hepatic artery.

in 3.1% (2) cases from an accessory right hepatic branch of superior mesenteric artery.

Their study revealed about the relationship of cystic artery and the duct system.

In 69.8% (405/500) cases, cystic artery arose from right hepatic artery in calot's triangle which was regularly described as normal. In 21.2% (123/500) cases, it crossed ventral to common hepatic duct. In 2% (12/500) cases, it crossed dorsal to common hepatic duct. In 3% (17/500) it crossed ventral to common bile duct. in 0.52%(3/500) it crossed dorsal to common bile duct. In 1.05% (6/500) cases cystic artery arose from right hepatic artery in the interval between the right and left hepatic ducts, crossing the right hepatic duct anteriorly to reach the gallbladder. In 1.05% (6/500) cases, it arose to the right of the duct system and crossed superiorly to cross the cystic duct. In 0.17% (1) cases artery is posterior to cystic duct. In 1% (5) cases it is entirely to the right of the duct system, crossing neither the common hepatic duct, cystic duct nor common bile duct. In 0.34% (2) cases, it arose with in portal fissure as a high point it crossed ventral to right & left hepatic ducts to reach the gall bladder.

Edward H. Daseler et al., from the above same series, worked in 500 cases to show 12 major anomalies in the ducts of liver. They were as follows.

- accessory right hepatic duct entered the Common bile duct in 1 case.
- cystic duct drained directly into the right hepatic duct in 3 cases.
- accessory right hepatic duct drained to cystic duct in 3 cases.
- small accessory right hepatic duct drained directly to gall bladder in 2 cases.
- small hepatic duct from the right or quadrate lobes of liver which drained into common hepatic duct in 2 cases.
- cystic, right and left hepatic ducts joined together at a common point of fusion so that no common hepatic duct was formed in 1 case.[17]

Milroy Paul in (1948) from an operative finding, described that right hepatic duct opened into the gall bladder at Hartmann's pouch and left hepatic duct continues as common hepatic duct and the cystic duct opened into the common hepatic duct.[18]

Charles B. Ripstein M.D., and G. Gavin Miller, M.D., in (1948) described about choledochus cyst associated with congenital atresia of gall bladder.[19]

Moosman, in 1948 from a dissection of about 147 cadavers, described about moosman's area which was about the size of half a dollar centering around the cystohepatic angle.

He also stated that it was the most critical angle and found within this, was cystic artery in 90%, right hepatic artery in 82%, all the accessory right hepatic arteries in 95% and 23 accessory bile ducts in 91%.[20]

Nicholas A. Michels, M.A., D.Sc., (1951), statistically estimated about the origins of cystic artery from 200 bodies.

Typically the cystic artery arises from coeliac right hepatic to the right of the hepatic duct in calot's triangle, after a short, medium or long course, it divides into superficial and deep branch. The superficial branch passes to the free peritoneal surface of gall bladder and the deep branch to the non peritoneal surface of gall bladder.

In about 1/4th of the subjects, the superficial and deep branches of the cystic artery have a separate origin. The deep cystic arises from right hepatic, superficial from right hepatic or from other sources namely left hepatic, hepatic proper, retroduodenal and gastroduodenal arteries.

Single cystic artery:

In the 200 bodies, cystic artery was single in 75% of cases. Out of which 70%(140), arises from coeliac right hepatic. In 5% (10%), it arises from left hepatic, hepatic proper, retroduodenal or gastroduodenal arteries.

Double cystic artery:

In 25% (50) cases, the superficial and deep branches arise separately from the same artery or from different sources. The 50 cases of double cystic comprised 12 types.

in 14.5% cases, both the superficial and deep cystic arteries branch with in the calot's triangle.

in 7% cases, only deep cystic artery is seen in the calot's triangle.

in 2% cases, only superficial cystic artery is seen in calot's triangle.

in 1% cases did not contain the origin of cystic from the right hepatic artery in the triangle.

in 3.5% two accessory hepatic ducts present, the two joined the hepaticduct or one joined the right branch of hepaticduct, the other the hepaticduct.

He observed the aberrant right hepatic artery in 26% (52) of cases. Of which 18% (36) were replaced right hepatic and 8% (16) were accessory right hepatic. The most common site of origin of an aberrant right hepatic artery is superior mesenteric artery.

In their study on the biliary ducts, the incidence of accessory hepatic ducts is greater having been observed in 18% (36) cases.

in 10% they joined the hepatic duct.

in 3.5% they terminated in the right branch of hepatic duct.

in 1% they joined the common bile duct.

The arterial relations to accessory hepatic ducts are surgically dangerous and difficult to analyse. The course of the right hepatic artery may be above or below the accessory ducts. The cystic artery may cross anterior or posterior to it or it may arise below or above it. When the cystic artery arises from right hepatic artery it passes posterior to common hepatic duct. If it arises from other sources it crosses anterior to common hepatic duct.

In 88% of cases right hepatic artery crosses posterior to common hepatic duct and in 12% of cases it crosses anterior to common hepatic duct.[21]

Edward V. Johnston and Barry J. Anson, Ph.D., (1952), by studying 35 specimens described,

I. The union of cystic with hepatic ducts

1. cystic duct joins the common hepatic duct at an acute angle in 18 cases which was described as angular type.

2. cystic duct and common hepatic duct may run parallel to each other for a varying distance. They are held by firm tissue, which may be indistinguishable on gross inspection.

They also classified the ducts with a parallel course, shorter than 2 cm, belonging to acute angular type (4 cases); 2 to 4 cm as short parallel (6 cases); 4 cm and over as long parallel type (1 case). The average length of the parallel course was 2.7 cm.

3. cystic duct winds round the hepatic duct for a quarter turn, half way or more or even a through full turn described as spiral type. The actual

point of junction may be on the anterior, posterior or the medial or left surface of common hepatic duct. 6 cases showed spiral type of union, of these 5 were posterior and 1 was anterior.

II. They also stated about the length of the ducts,

The length of the common bile duct varied with the overall body size, level of duodenum and the point at which the cystic duct joins with the common hepatic duct.

Statistics on the length of the common bile duct, common hepatic duct and cystic duct were directly affected by the recognition and careful dissection of long and short parallel type of junction of the latter two types.

Table A shows the differences in average measurements of common bile duct as affected by this parallelism.

III. Their study on the common hepatic duct alone,

1. presence of common hepatic duct in 34 specimens(97%)

2. extrahepatic formation of common hepatic duct 32/34 specimens(93.3%)

3. average length of the common hepatic duct ranges from 2 to 3.5 cms.

4. it is absent when the cystic duct emptied at the point of junction of right and left hepatic ducts, or if the cystic duct enters at an even higher level by joining one of the hepatic ducts, usually right hepatic duct.

5. measurements of common hepatic duct is mostly affected by the level at which the cystic duct emptied the common hepatic duct.

Table B gives the length of common hepatic duct in relation to the type of cystohepatic duct junction with a record of the differences between the initial gross appearance and after cross separation of the parallel ducts.[22]

Henry Hollinshead, in 1954, commented about the term “hepatic pedicle”, as it is commonly used to designate the upper end of “hepatoduodenal ligament” and the structures, which it contains.

The three structures namely common bile duct, normally lies anterior and to the right, in the actual edge of hepatoduodenal ligament, while the hepatic artery also lies anterior just to the left of the common bile duct, the portal vein larger lies behind the duct and artery to the left of the duct shown in (Pic.4).

In his description, he says “variations in the length of the hepatic and cystic ducts are quiet common”.

The length of common hepatic duct is usually determined by the respective levels of union of two proper hepatic ducts and the level at which it is joined by the cystic duct.

The length of common hepatic duct varies from 2.5 to 7.5 cms. The length of common bile duct varies from 5 to 15 cms. The length of cystic duct is 5 cms. The angle of union between the cystic and hepatic ducts also varies.

Cystic duct sometimes joins the hepatic duct at almost a right angle. Sometimes, parallels it for some distance before joining common hepatic duct. Sometimes cystic duct may pass behind or in front of common hepatic duct to empty into the left side to form a spiral course (Pic.4a).

According to him the most common and usually the most important variations in the arterial system is related to the two vessels, namely, right hepatic artery and cystic artery, since these two vessels lie with in the calot's triangle.

Some variations in the course and relationship of a right hepatic artery are given the (Pic.4b).

It is usually the right hepatic artery which presents itself in the area of danger in biliary surgery, the manner in which it enters calot's triangle and its relations with in the triangle subject to variation.

Normally, the right hepatic artery passes dorsal to the common bile duct or common hepatic duct but, it can also pass ventral to both these ducts.

More over the artery is in close contact with the cystic duct, either paralleling it or bulging forwards or to the right.

The common anomalies of cystic artery encountered by him were

1. doubling of cystic artery.
2. origin to the left of common bile duct and of the common hepatic duct.
3. an origin to the left of the calot's triangle.
4. passes ventral to common hepatic or common bile ducts.

Some variations in the origin and course of the cystic artery is given in the (Pic.4c).[23]

Carington William M.D., et al., in 1955, stated that the most frequent anomalies of the ductal system were the accessory ducts. Almost these accessory ducts arose from the right lobe of the liver and most of them emptied into the gall bladder, a few entered the cystic duct.

They also added that the division of the small ducts could be readily overlooked and may not be suspected until there was drainage of bile through the wound.[2]

G.Hossein Mahour M.D., et al., in 1961, studied 100 autopsies and described about the height of termination of cystic duct.

In 80% of cases, the cystic duct terminates by running obliquely downwards to the junction of common hepatic duct. This type gives a short hepaticus and longer common duct.

In 18% of cases its downward course is steeper and terminates so low so that hepatic duct is longer than the common duct.

In 1.5% cases cystic duct courses upwards and terminates close to the bifurcation in 0.5%, in the bifurcation in 0.25% to the right hepatic duct in 0.75%.[24]

Deward O. Ferris, M.D., et al., in 1965, from a case study found absence of cystic duct with normal biliary tree which was confirmed by cholangiography.[25]

Levin and Saksenberg et al., in 1980, reported a case of left sided gall bladder and left side bile duct in the absence of situs inversus.[26]

Paul H, Sugarbaker, M.D., et al., in 1985, from a case report during operation on hepatoduodenal ligament, revealed two cystic ducts, each communicates independently with common bile duct and the right hepatic artery was placed anterior to the Common bile duct. He also noted the presence of two cystic arteries arising from right hepatic artery to enter gall bladder independently.[27]

Stremple JF in 1986, stressed upon the need for careful operative dissection in moosan's area during cholecystectomy.[28]

The southern surgeon club, during 1991, mentioned that in 1518 laparoscopic cholecystectomies performed by 59 surgeons, 4.7% was converted to open cholecystectomy due to presence of aberrant anatomy.[29]

Ricardio L. Rossi M.D., et al., in 1992, gave a review of 11 patients, who underwent biliary reconstruction after laparoscopic cholecystectomy, in which ductal injuries occurred due to failure to define the ductal anatomy and of the calot's triangle.[30]

A.R. Mossa, M.D., et al., 1992 mentioned that laparoscopically it is not conveniently possible to begin the dissection at the fundus of gall bladder as that in open cholecystectomy, in order to avoid injuries.

So, in order to avoid injuries during laparoscopic cholecystectomy, the ductal lengths are to be noted and the variations of ductal anatomy should be made out.[31]

According to **Andrew M. Ress M.D., et al. (1993),** bile duct injuries were far more common and constituted 86% of laparoscopic complications. So, routine laparoscopic cholangiography, via gall bladder prior to dissection of calot's triangle or routine cystic duct cholangiography has been advocated to clear the anatomy of biliary system to prevent biliary tract injuries.[32]

Juan R. Madariaga, M.D., F.A.C.S., et al., in 1994, gave a study design on 15 patients with complex laparoscopic cholecystectomy injuries who underwent corrective surgery. The injuries consisted of 14 bile ducts. They finally concluded that knowledge of anatomy is critical in prevention of injuries to the hepatobiliary tree and related structures during laparoscopic cholecystectomy.[33]

L.H. Blumgart, during 1995, observed that extrahepatic biliary ducts are represented by extrahepatic segments of right and left ducts, joining to form common hepatic duct. In that extrahepatic segment of right hepatic duct is shorter but the left duct has a much longer course. [34]

Balija et al., in 1999, presented a laparoscopic visualization and classification of various origins of cystic artery which is shown in the (Pic.5).[3]

Fritscher Ravers et al., in 2000 stated that in comparison of laparoscopic cholecystectomy with open cholecystectomy, laparoscopic cholecystectomy is associated with the higher incidence of bile duct injuries and one of the reasons for that was failure to recognize the anatomical variations of that area.[35]

Nicholas et al., in 2002, described that anatomical location of the bile ducts and the related structures are important for conventionally classifying or for grading of the tumors of hilar cholangiocarcinoma.[36]

Strasberg S.M., (2002), in a paper on avoidance of biliary injury during laparoscopic cholecystectomy, mentioned that careful dissection and cautery usage in the triangle of calot is needed.[37]

From the **Journal of Gastrointestinal Endoscopy (2003),** the approach to the patient with hilar cholangiocarcinoma involving the bifurcation requires definition of the anatomy to determine operative respectability. Magnetic Resonance Cholagio Pancreatography (MRCP) and Magnetic Resonance Imaging (MRI) should be performed to determine the ductal anatomy.[38]

M Hribenik et al., in 2003, did a study of variations of proximal extrahepatic bile duct, which revealed that overlooked and surgically mistreated variations could be the cause of post operative bilomas, partial atrophies of the remnant liver after resections.[39]

Sharif K. deville de Goyet J. (2003), states that variations of biliary anatomy in gall bladder bed and cholecysto – hepatic triangle of calot are reviewed,in order to avoid bile leakage after cholecystectomy.[40]

Tomoz Benedik et al. (2003), in their principles of safety laparoscopic cholecystectomy article concluded that to avoid misidentification of ducts one should conclusively identify cystic duct and cystic artery, the two structures to be divided in every cholecystectomy. To achieve that goal, calot's triangle must be dissected free of fat and fibrous tissue.[41]

Masanori Asanda, M.D., et al., during 2003, explains that in living donor liver transplantation (LDLT), the duct to duct biliary reconstruction, requires perfect anatomical location of the biliary system that of duct arising from right lobe. Since the study in 51 liver donors, it was observed that 19(37%) had double bile ducts with separate orifice, duct to duct reconstruction with right lobe living donor transplants therefore is often more complicated.[42]

Kyng Suk Sub M.D., Ph.D., et al., in 2004, also, explained that peri operative evaluation of the anatomy of the bile duct before living donar liver transplantation is done through Magnetic Resonance Cholagiography (MRC) and Intra operative Cholangiography (OPC). With OPC, the anatomy of the intrahepatic and extrahepatic biliary tree can be explained.[43]

In the latest edition of Gray's Anatomy (2005), regarding the variations occurring in cystic duct, it is mentioned that rarely cystic duct lies along the right edge of lesser omentum, all the way down to the level of duodenum, before the junction is found. But in these cases cystic duct and common bile duct are usually closely adherent.

Cystic duct occasionally drains into right hepatic duct in which case it may be elongated lying anterior or posterior to common hepatic duct and joins the right hepatic duct on its left border.

Rarely the cystic duct is double or even absent in which case the gall bladder drains directly into the common bile duct.

One or more accessory hepatic ducts occasionally emerge from the segment five of liver and join either the right hepatic duct, left hepatic duct, common bile duct, cystic duct or gall bladder directly.

He also mentioned that ligation or clip occlusion of cystic duct must be performed at an adequate distance from the common bile duct to prevent angulation or damage to it. Accessory ducts must not be confused with right hepatic or common hepatic ducts.

Regarding the vessels related to the duct system cystic artery usually arises from right hepatic artery. It passes posterior to common hepatic duct and anterior to cystic duct to reach the superior aspect of gall bladder and divides into superficial and deep branches.

Cystic artery may arise from common hepatic artery, left hepatic artery, gastro duodenal or superior mesenteric artery. In these cases it lies anterior to common hepatic duct and common bile duct.

An accessory cystic artery may arise from common hepatic artery or one of its branches and it often bifurcates close to its origin giving rise to two vessels which approach gall bladder.

The near triangular space formed between the cystic duct, common hepatic duct and the inferior surface of segment five of liver has been described as calot's triangle. It is enclosed by double layer of peritoneum. This space usually contains cystic artery, cystic lymph nodes, one or two cystic veins. It may also contain any accessory ducts which drain into gall bladder from liver.[44]

MATERIALS AND METHODS

Study Materials :

The study materials consisted of :

A. 1. 15 adult dissection room cadavers

2. 25 enbloc postmortem specimens

3. 5 deadborn foetuses between 7 and 9 months old

B. 15 cases of radiological study

C. 5 cases of clinical study

D. Cast Study

A. SPECIMEN COLLECTION :

1. 15 adult dissection room cadaver specimens were studied insitu.

2. 25 postmortem enbloc specimens were collected from the Institute of Forensic Medicine, Madras Medical College, Chennai. They were studied by conventional dissection method.

The autopsies had been carried out by laparotomy midline incision from xiphisternum towards umbilicus. Incision extended laterally, from xiphisternum along the costal margin.

Rectus muscle cut open in the midline. Peritoneum opened and entered into abdominal cavity. Stomach identified and its curvatures were defined. Pulling the lesser curvature, lesser omentum identified and its right free margin was defined and then hepatoduoneal ligament was identified. Now the greater omentum was cut transversely below the stomach and it was pushed upwards towards right. Coils of small intestine was pushed towards left and 2nd part of duodenum was exposed and two ligatures were put, one at the pyloric end of stomach and second just below the second part of duodenum.

Now, the stomach was reflected fully upwards to expose the pancreas and then it was cut at the level of neck. This makes the visceral surface of liver free, along with duodenum and head of pancreas.

Now, to make the parietal surface of liver free, the ribs were cut open along the midaxillary line on both sides and reflected upwards along with sternum.

Inferiorvenacava identified and cut, and now the liver along with gall bladder, duodenum and head of pancreas was removed in toto.

They were transported in closed plastic containers to the institute of anatomy for further dissection.

3. 7 to 9 months old dead born foetuses were collected from the Institute of Obstetrics and Gynecology, Madras Medical College, Chennai and were preserved in separate containers.

METHOD OF STUDY

DISSECTION OF POSTMORTEM SPECIMENS :

After thorough washing of the specimens in running water, the hepatoduodenal ligament was opened by tracing the bileduct upwards and to secure the point where the cystic duct and common hepatic duct unites. Cystic duct traced upwards upto the neck of gall bladder common. Hepatic duct was then traced upwards to locate the right and left duct emerging from portahepatis. Lateral to the duct system towards left the common hepatic artery was identified and traced upwards where it divides into right and left hepatic arteries. From the right hepatic artery, cystic artery was identified and traced. The boundaries of calot's triangle were defined and the cystic artery inside the triangle was traced upto gall bladder. Posterior to all above structures, the portalvein was defined. During the above procedures, the mode of the formation the duct system, the course and arrangement of the ducts, the mode of termination along with the related vessels were study. Then length of the individually ducts were measured.

After dissection, the specimens were immersed in the following preservative solution and kept in separate containers.

The preservation solution contains,

10 litres of normal saline

1 litre of 10% formalin

50 ml of glycerine

5 gm of powdered thymol

100 gm of detergent powder

B. RADIOLOGICAL STUDY

1. MRCP - Magnetic Resonance Cholangiopancreatography Study.

This study was conducted in 10 patients in Bernaurd Institute of Radiology, Government General Hospital, Chennai.

MRCP is an imaging technique used to evaluate the biliary system. The basic principal of MR Cholangiopancreatography is to utilise T_2 weighted images where stationary or slowly moving fluid including bile is high in signal intensity and all the surrounding tissues including retroperitoneal fat and the solid visceral organs are lower in signal.

Patients were instructed to be on nil oral for 6 hours or iron oxidase, was given to the patients and conventional pictures were take both in thick and thin sections[49].

2. Direct Cholangiography

This study was conducted in 5 patients from Bernaurd Institute of Radiology, Government General Hospital, Chennai.

Chiba needle was inserted in mid - axillary line in the eight or ninth rib during suspended inspiration parallel to table top 20 - 30 degree cephalad in the direction of the xiphisternum until just short of the right- lateral margin of spine. Non ionic contrast was injected, while the needle is slowly withdrawn and pictures taken, in multiple sections[50].

C. CLINICAL STUDY

The study was undertaken in 5 patients who under went laparoscopic cholecystectomy. Under general anesthesia a 5 or 10 mm laparoscope is inserted into the abdomen through the umbilical part. The patient is then placed in a reverse trendelenburg position of 30°, while rotating the table to the left by 15°. The gall bladder can usually be seen protruding beyond the edge of liver.

2 accessory subcostal ports are then placed under direct vision along the right anterior axillary line and right midclavicular line to secure the gallbladder. A final operating trocar is placed in the midline of epigastrium.

The fibro - areolar structures overlying the infundibulum of gallbladder was dissected out. Structures forming the calot's triangle were defined out. The cystic artery was separated from the surrounding tissue by blunt dissection. The neck of the gall bladder was dissected out away from its liver bed.

Prior to this procedure a double clip was applied to cysticduct and divided proximally. Then cystic artery was dissected from the surrounding tissue for an adequate distance to permit placement of 3 clips.

Then the gallbladder separated away from its hepatic bed was then initiated using an electrosurgical probe to coagulate small vessels and lymphatics. The final attachments of the gall bladder were divided and the liver edge was again examined for complete hemostasis.

After cholecystectomy the gall bladder is removed from the abdominal cavity through umbilical port site[46].

D. CAST STUDY

Four fresh specimens were washed in running water. Normal saline was injected into the common bile duct flushed and milked thoroughly to remove the bile. Then heparin was injected to dislodge any blood clots. The right and left hepatic ducts emerging from porta hepatis were tied. Then 30 ml of latex emulsion was injected into the common bile duct and tied. Then it was immersed, in the concentrated solution of potassium hydroxide overnight. Gradually the epithelium above it got destroyed by itself and the duct system was obtained and washed thoroughly.

OBSERVATION

The observed findings by dissecting 40 adult human specimens including 25 enbloc post mortem specimens and 15 adult human cadavers were given under the following headings.

I. FORMATION OF COMMON HEPATIC DUCT:

1. Extrahepatic union of right and left hepatic ducts:

The right and left hepatic ducts united outside the porta hepatis to form the common hepatic duct in 25/40 (62.5%) specimens (Pic.6).

2. Intrahepatic union of right and left hepatic ducts:

In the remaining 15/40 specimens (37.5%), the right and left ducts united intrahepatically and common hepatic duct emerged from the substance of liver at porta hepatis (Pic.7).

II.A. TYPES OF UNION OF CYSTIC DUCT WITH COMMON HEPATIC DUCT:

There are three types of union of cystic duct with common hepatic duct.

i. Angular type:

In this type, cystic duct makes an acute angle to join with the common hepatic duct. This type of union was observed in 30 specimens (75%), in the present study (Pic.8).

In all the specimens, cystic duct united at the right side of common hepatic duct. In one case, cystic duct was seen at the left side of common hepatic duct and unites with common hepatic duct at its left side. **(Specimen No.35)** without any situs invertus.

ii. Parallel type:

In this type, cystic duct runs parallel with common hepatic duct for a varying distance before it unites with common hepatic duct. 10 specimens (25%) were observed to be parallel type of union in this study, (Pic.9).

iii. Spiral type:

The cystic duct makes a spiral course before joining with common hepatic duct either on antero lateral or posterolateral side of it.

In the present study, none of the specimens were found to be of spiral type of union.

B. LEVEL OF TERMINATION OF CYSTIC DUCT:

The point at which the cystic duct joins the common hepatic duct is either at a high level, at a low level or at normal level.

1. High level of union:

Here, the cystic duct joins the common hepatic duct close to the bifurcation of right and left hepatic ducts. This type of union makes the common hepatic duct shorter and the Common bile duct longer (Pic.10).

The normal length of common hepatic duct as given in Gray's is 3 cm.

In high level of union the common hepatic duct length ranges from 1 to 1.5 cm.

2. Low level of union:

In this type, the cystic duct joins the common hepatic duct further away from the bifurcation.

In low level of union of the common hepatic duct length is longer than the common bile duct.

In the present series, normal level of union was observed in 30 (75%) specimens.

High level of union cystic duct with common hepatic duct was noted in 10 specimens(25%). (**specimen nos. 13, 17, 19, 21, 22, 23, 28 , 35, 38, 39**)

Low level of union of cystic duct with common hepatic duct was not found in this study.

In one case of radiological study, low union of cystic duct with common hepatic duct was noted.

III. LENGTH OF INDIVIDUAL DUCTS:

Table C gives the length of the cystic duct, common hepatic duct, common bile duct and accessory ducts, if present.

Table - C

Specimen No.	Length of Cystic Duct (cm)	Length of common hepatic duct (cm)	Length of common bile duct (cm)	Length of accessory ducts (cm)
1.	4	3	7	
2.	2.5	3	6.5	0.5
3.	3	3	7	1.5
4.	3.5	3	6	
5.	3	2.5	5	
6.	2.5	3	5.5	
7.	1.5	2.5	6.5	
8.	3	2	7.5	
9.	3.5	3.5	8	
10.	3	3.5	7	1.5
11.	2.5	2.5	8	
12.	3	3	7.5	
13.	2	1.5	7	
14.	2.5	2	6.5	
15.	3	2.5	7	
16.	3	2.5	8	
17.	1	1.5	7.5	

18.	2.5	2	7	
19.	2	1.5	6.5	
20.	1	2	7	0.5
21.	2.5	1.5	8	
22.	1	1.5	5	
23.	1	1	5	
24.	3.5	2	6.5	
25.	2.5	3	7	2
26.	1.5	2.5	6.5	0.5
27.	2.5	3	8	
28.	2	1.5	8	
29.	1	2	7.5	0.5
30.	1.5	3	6	0.5
31.	3	2.5	6	
32.	3	2.5	6.5	
33.	2.5	2	8	
34.	1.5	2	6.5	
35.	To the left side of CHD 2	To the right side of CD 1.5	7	
36.	2.5	2	7.5	
37.	1	1.5	7.5	
38.	2	2.5	6.5	
39.	0.5	1	6	
40.	2	2.5	6	1.5

IV. COURSE AND ARRANGEMENT OF STRUCTURES IN HEPATODUODENAL LIGAMENT:

The normal arrangement of structures in hepatoduodenal ligament as given in Hollinshead is that common bile duct lies anterior and to the right in the actual edge of hepatoduodenal ligament. Hepatic artery lies anterior just to the left of Common Bile duct. Portal vein lies behind the duct and artery and is usually larger and to the left of the duct.

This normal arrangement was noted in 39/40 specimens.

The arrangement of these structures was found to be varied in one specimen.**(specimen No.35)** (Pic.11, 11a).

The variations observed in specimen no.35 are given below,

1. Cystic duct joined the left side of the common hepatic duct.

2. The hepatic artery proper was found to lie on the extreme left and divides into three branches, namely,

   i) right hepatic artery

   ii) superficial branch of cystic artery

   iii) left hepatic artery.

3. The right hepatic artery passed behind the common hepatic duct and ran parallel to it outside the calot's triangle to dip into the right lobe of liver. From the right hepatic artery, deep branch of cystic artery arose and passed upwards inside the calot's triangle to reach the gall bladder bed.

4. Superficial branch of cystic artery arising from hepatic artery proper ran upwards, parallel and close to the cystic duct on the left side to reach the anterior surface of gall bladder.

5. Left hepatic artery arising from the hepatic artery proper passed to the left of the duct to reach the left lobe of liver.

6. Portal vein larger and behind the duct and artery was seen on the extreme right of common bile duct.

Hence in specimen no.35,

i) The hepatic artery divides into 3 branches, right hepatic artery, superficial branch of cystic artery and left hepatic artery.

ii) Right hepatic artery is seen outside the calot's triangle.

iii) The common bile duct lies between the artery and portal vein.

iv) Portal vein is behind the duct and artery and to the extreme right side.

V. VARIATIONS IN DUCTAL SYSTEM:

The variations in the extrahepatic ductal system were observed under the following headings.

1. Presence of accessory ducts

2. Mode of termination of accessory ducts

By dissecting 40 specimens, a total of 9 accessory ducts were noted. Out of which, 7 were accessory right hepatic ducts and 2 were accessory cystic ducts. Accessory ducts emerging from the left lobe of liver were not observed in this study.

The details of the accessory right hepatic and cystic ducts are given below.

A. Accessory right hepatic ducts (totally 7 specimens):

i) In **specimen No.2**, presence of a small accessory right hepatic duct, arising close to inferior surface of gall bladder was visualized. It descends downwards coursing parallel to the left hepatic duct, to terminate in the common hepatic duct, just below the union of right and left hepatic ducts.

A small branch, arising from cystic artery supplying the accessory right hepatic duct was also traced out (Pic.12).

ii) From **specimen No.3**, a small accessory hepatic duct emerging from the right lobe of liver was dissected. It winds round between the 2 divisions of cystic artery. The mode of termination of the accessory right hepatic duct is that it opens in the middle of the common hepatic duct (Pic.13).

iii) **Specimen No.10,** presents with an accessory right hepatic duct. It emerges below the two divisions of cystic artery running downwards and parallel to common hepatic duct. Just above the junction of cystic duct with common hepatic duct it joins the common hepatic duct, in its lower half (Pic.14).

iv) In **specimen No.20**, a small accessory right hepatic duct arising close to the gall bladder fossa was seen. It passes below and close to the lower half of common hepatic duct, just above the union of cystic duct with common hepatic duct (Pic.15).

v) **Specimen No.25** shows an accessory hepatic duct arising closer to the gall bladder fossa emerging from the right lobe of liver. It courses above and parallel to the cystic artery. It drains into the upper half of the common hepatic duct just below the left hepatic duct (Pic.16).

vi) From **specimen No.30**, an accessory right hepatic duct emerging from the quadrate lobe of liver was observed. It runs downwards and parallel to common hepatic duct to join the cystic duct, at the junction of cystic duct with common hepatic duct. This duct was crossed by cystic artery inside the calot's triangle (Pic.17).

vii) **Specimen No.40** has an accessory hepatic duct emerging from the right lobe of liver. It descends downwards parallel to the right deep branch of cystic artery. It terminates by passing below the superficial branch of cystic artery to reach the middle of common hepatic duct where it opens into it (Pic.18).

B. Accessory cystic ducts (totally 2 specimens):

i) In **specimen No.26,** a small accessory cystic duct emerging from the inferior surface of gall bladder was dissected. It runs downwards, close and parallel to the common hepatic duct and drains into common hepatic duct, close to the junction of cystic duct and common hepatic duct (Pic.7).

ii) **Specimen No.29** presents with a small accessory cystic duct arising from the anterior surface of gall bladder, just above the Hartmann's pouch. It descends downwards close and parallel to the cystic duct to terminate in the middle of cystic duct itself.

A small arterial twig arising from the accessory replacing type of cystic artery to the supply the accessory cystic duct could be able to be traced out (Pic.19, 19a).

The frequency of occurrence of accessory ducts was 22.5% in this study.

Hence from the present study,

Out of 7 accessory right hepatic ducts, 6 terminate in the common hepatic duct, at various levels and one accessory right hepatic duct terminates in the cystic duct.

To add more, regarding the various levels of terminations of the accessory ducts

- In 2 cases accessory right hepatic ducts terminates in the upper half of common hepatic duct, close to the bifurcation of right and left hepatic ducts.
- In 2 other specimens, the accessory right hepatic ducts terminate in the middle of Common hepatic duct.

- In 2 cadavers, the accessory right hepatic ducts terminates in the lower half of Common hepatic duct.

- In 1 specimen, the accessory right hepatic duct terminates in cystic duct.

- Out of 2 accessory cystic ducts noted, one terminates in the Common hepatic duct and the other in the cystic duct itself.

Arterial supply to these accessory ducts could be able to be traced out in 2 specimens only. One for an accessory right hepatic duct and the other for an accessory cystic duct.

VI. VARIATIONS IN ARTERIAL SYSTEM RELATED TO DUCT SYSTEM :

The two main arteries related to extrahepatic duct system are cystic artery and right hepatic artery.

The cystic artery, normally arising from the right hepatic artery with in the calot's triangle, passes in the triangle, towards the neck of gall bladder, where it typically divides into superficial and deep branches. The superficial branch passes on its peripheral surface, while the deep branch runs on the attached surface of gall bladder.

As given in Hollinshead,

The common subdivision of aberrant arteries into accessory and replacing ones, based upon the extrahepatic dissection of the vessels is that, the term "accessory" implies at least the passive assumption that artery so named is one of two or more to a given part of the liver and that these arteries anastomose freely in supplying that part of the liver.

Similarly, the term “replacing” implies that the vessel so named is the sole supply to a given portion of the liver and has been used to denote only a vessel of aberrant origin which supplied the entire liver or one which appeared to be the only supply of an entire lobe of the liver.

- **Specimen No.4** presents with double cystic artery. In this both the superficial and deep branches arise separately from the right hepatic artery itself. Both the branches are seen inside the calot’s triangle. They run parallel to the cystic ducts to reach the respective surfaces of gall bladder (Pic.20).

- In **specimen No.8**, an aberrant replacing cystic artery was visualized. This arises from aberrant right hepatic artery (Pic.9).

In this, cystic artery arises from a replaced right hepatic artery from superior mesenteric artery. This aberrant replacing cystic artery is seen to lie on the right side of the common hepatic duct.

- **Specimen No.10** shows, presence of an accessory cystic artery.

It arises from the hepatic artery proper running upwards towards right, crossing ventral to the common hepatic duct to reach the anterior surface of gall bladder and sending small twigs to supply it.

In addition to the accessory cystic artery it also shows presence of normal cystic artery arising from the right hepatic artery. It divides into superficial and deep branches inside the calot’s triangle (Pic.14).

- In specimen no.23, cystic artery arising from right hepatic artery is visualized. It passes ventral to common hepatic duct to reach the anterior surface of the gall bladder; whereas the usual course of cystic artery is dorsal to common hepatic duct.

Right hepatic artery was seen at a higher division close to porta hepatis, arising from the hepatic proper (Pic.21).

- **Specimen No.22**, gives cystic artery issuing from common hepatic artery, passing ventral to common hepatic duct to reach gall bladder.

Right hepatic artery is also visualized arising from hepatic proper. It lies to the left of the common hepatic duct, dipping inside the substance of liver to supply the right lobe (Pic.22).

- In **specimen No.29,** aberrant replacing cystic artery is noted, from aberrant accessory right hepatic artery. In this the cystic artery arises from an accessory right hepatic artery from the superior mesenteric artery.

This artery ascends upwards, straight behind the common bile duct and also passes behind the cystic duct to reach the calot's triangle. Inside the triangle, it divides into superficial and deep branches. A small twig of this cystic artery, which supplies the accessory cystic duct, was able to be traced out.

The normal right hepatic artery was also be made out. This right hepatic artery arising from the hepatic proper was observed to have a high division of origin from hepatic proper close to porta hepatis. This artery is seen to the left of the duct system passing inside to supply the right lobe of liver (Pic.19, 19a).

- From **specimen No.39**, both the right hepatic and cystic arteries are seen at a higher division of origin close to the porta hepatis.

The cystic artery was found to be from the right hepatic artery, but passing ventral to common hepatic duct, to reach the anterior surface of gall bladder. The usual course of it was that it passes dorsal to common hepatic duct to reach the gall bladder. The origin of the cystic artery is found to be very high close to substance of liver.

The right hepatic artery arising from hepatic proper is also noted. This artery is also found to be higher division close to the substance of liver, to the left side of the duct system (Pic.23).

- In **specimen No.30**, the origins of the cystic artery and right hepaticartery were noted to be normal.

But both the right hepatic and cystic arteries were passing anterior to common hepatic duct (Pic.17).

VII. CALOT'S TRIANGLE:

Hollinshead states that, the boundaries of calot's triangle are common hepatic duct on the left side, cystic duct on the right side and hilum of liver above.

The two important vessels that lie inside the triangle are right hepatic artery and cystic artery.

The study of the calot's triangle was conducted under two headings.

1. Boundaries
2. Contents

1. Boundaries:

In the present series of 40 specimens, the boundaries of the calot's triangle were defined in 39 specimens.

Specimen No.35 shows cystic duct on the left side, common hepatic duct on the right side and hilum of liver above (Pic.11).

2. Contents:

The usual contents of calot's triangle are the right hepatic artery and cystic artery. In addition to these two usual contents, the following specimens show variations, which are described below.

In 31/40 specimens, the contents of the calot's triangle were observed to be normal, including the altered side boundary of calot's triangle in specimen no.39.

In the remaining 9 specimens,

i) Presence of accessory hepatic ducts, all emerging from the right side of liver was noted in 6 specimens.

ii) Presence of double cystic arteries in one specimen.

iii) Presence of aberrant accessory cystic artery from aberrant accessory right hepatic artery in one specimen.

iv) Cystic artery branch from the right hepatic artery, not seen inside the calot's triangle and is given outside the triangle from hepatic proper in one specimen.

FOETAL STUDY

5 foetal specimens were dissected and traced out to find the extrahepatic duct system with its related vessels and are dissected under the following headings.

I. Formation of common hepatic duct:

i) extrahepatic union of right and left hepatic ducts were seen in foetal specimen no.1 and specimen no.4

ii) intrahepatic union of right and left hepatic ducts were seen in foetal specimen no.2, 3 and 5.

II. Types of union of cystic duct with common hepatic duct:

- Angular type of union was seen in 3 cases – foetal specimen no. 1,3 and 5.
- Parallel type of union was noted in 2 cases – foetal specimen no. 2 and 4.
- Spiral type was not observed in this study.

III. Length of the individual ducts:

Table D shows the lengths of the cystic duct, common hepatic duct and common bile duct, in cms.

Table - D

Specimen No.	Length of cystic duct (cm)	Length of common hepatic duct (cm)	Length of common bile duct (cm)
1.	0.5	1	3
2.	3	0.5	-
3.	1	2	3
4.	1.5	1	4
5.	1	1	3

IV. ARRANGEMENT OF STRUCTURES IN HEPATODUODENAL LIGAMENT:

In all the 5 foetal specimens the structures were arranged in normal pattern.

V. VARIATIONS IN DUCTAL SYSTEM:

In foetal **specimen No.2**, the cystic duct was observed as long emerging from the neck of gall bladder, passing downwards and terminating directly into the 2nd part of duodenum.

Common hepatic duct is very small and joins the cystic duct at the neck of the gall bladder.

In this foetal specimen, common bile duct could not be made out (Pic.25).

In all other specimens the ductal system appeared to be normal and no accessory ducts were found.

VI. VARIATIONS IN ARTERIAL SYSTEM:

- **In foetal specimen No.5**, presence of an aberrant accessory cystic artery passing to the right of common bile duct was noted, which supplies the anterior surface of gallbladder.

In addition to this, cystic artery, arising from the normal right hepatic artery inside the calot's triangle was found (Pic.28).

- All other specimens no.1,3,4 showed normal arterial pattern.
- In all the specimens cystic artery and right hepatic artery passed dorsal to the common hepatic duct.

VII. CALOT'S TRIANGLE:

The boundaries of the calot's triangle were defined in specimen no. 1, 3, 4 and 5. Calot's triangle shows normal pattern, both in the boundaries and contents, in all the specimens, except in specimen no. 2, which shows long cystic duct and a small common hepatic duct, just above the cystic duct. In this specimen calot's triangle could not be made out.

RADIOLOGICAL STUDY

A number of examination techniques are available for evaluating the biliary ductal system. But Magnetic Resonance Cholangiopancreatography (MRCP) is assuming a larger role in the evaluation of biliary ductal disease. The diagnostic accuracy of MRCP is comparable to that of ERCP (Endoscopic retrograde Cholangio Pacreatography) in location of anatomical variations of biliary tract also.

Hence, a study conducted in 10 patients who presented with various signs and symptoms suggestive of biliary disease was carried out in Bernaurd Institute of Radiology, Madras Medical College, Chennai.

- The right hepatic duct is formed by the union of the anterior and posterior segment ducts at the porta hepatis.

- The left hepatic duct is formed by union of medial segment duct and a left lateral segment duct.

The common anatomical variations observed in this study of MRCP are

1. Low insertion of cystic duct with common hepatic duct (Pic.29).

2. Drainage of right posterior duct into left hepatic duct before joining right anterior duct (Pic.30).

3. Cystic duct runs a parallel course with common hepatic duct for a varying distance and also termination of right posterior duct into left hepatic duct (Pic.31).

DISCUSSION

An extensive study on extrahepatic biliary passage was previously done by many authors. With due respect, I compare and quote the present study on 40 specimens with those of eminent workers.

I. Formation of common hepatic duct :

Site of union of right and left hepatic ducts

The right and left hepatic ducts from the corresponding lobes of liver unite to form common hepatic duct either extrahepatically or intrahepatically.

Brewer (1900) from dissection of 50 specimens found 100% extrahepatic union of right and left hepatic ducts.

Rugg (1908) studied 43 cadavers. In that he observed extrahepatic union of right and left hepatic ducts in 79% and intrahepatic union of right and left hepatic ducts in 21%.

Eisendrath (1918) gave similar reports as Brewer. He also observed 100% union of extrahepatic right and left hepatic ducts from 100 specimens.

Thompson dissected 50 specimens in 1933 and noted 90% extrahepatic union and 10% intrahepatic union of right and left hepatic ducts.

In the present study on 40 specimens extrahepatic union of right and left hepatic ducts was noted in 62.5% of cases and intrahepatic union of right and left hepatic ducts in 37.5% of cases.

On comparing the above studies extrahepatic union of right and left hepatic ducts is found to be more common than intrahepatic union.

II.A. Types of union of cystic duct with common hepatic duct :

The junction of cysticduct with common hepatic duct which is of surgical importance is highly variable. Three types of union of cystic duct with common hepatic duct are noted namely,

1. angular type 2. parallel type 3. Spiral type

43 cadavers were dissected by Rugg (1908) and he reported, angular type - 35%, parallel type - 20% and spiral type - 45%

Eisendrath's (1918) study on 100 specimens showed angular type - 75%, parallel type - 17% and spiral type - 8%.

Thompson (1933) dissected 50 cases and observed angular type - 90%, parallel type - 6% and spiral type - 4%.

An elaborate study of 194 cadavers was done by A. Lurje M.D., (1937). He stated angular type - 46.9%, parallel type - 30.9% and spiral type - 22.2%.

Edward V. Johnston (1952) in his work on 35 specimens, visualised angular type - 51.4%, parallel type - 31.4% and spiral type - 17.1%.

But in present study (2006), I observed angular type in 75%, parallel type in 25% and spiral type of union was not found.

This agrees with Eisendrath's study except in spiral type of union. On comparing the above studies, the most common type of union of cystic duct with common hepatic duct is angular type.

Surgical Importance :

In parallel type of union, both the cystic duct and common hepatic duct are closely bound together. Hence, their separation becomes difficult. Moreover, in parallel type of union, two ducts may closely adherent to eachother. So it is difficult to put a clamp without injuring common hepatic duct.

In addition to this, "cystic duct remanant syndrome" may occur in parallel type of union, with various sequelae leading to post cholecystectomy symptoms be being the site of chronic inflammation, lithiasis or neuroma formation[3].

Johnston and Anson reported that it is obvious that both parallel and spiral type of union presents difficulty in surgery[22].

B. Level of termination of cystic duct :

The level of termination of cystic duct with common hepatic ducts are :

1. High level 2. Low level 3. Normal level

In high level of union cystic duct unites with common hepatic duct close to the bifurcation of right and left hepatic ducts. In this level the common hepatic duct length is very small than its average and common bile duct length is more.

In low level of termination, cystic duct unites with common hepatic duct further away from the bifurcation to make common hepatic duct longer than common bile duct.

In Normal level of union common bile duct is longer than common hepatic duct.

Hossein Mahour in (1961), from a study on 100 autopsies, described about the height of termination of cystic duct. In that, in 80% of cases cystic duct runs obliquely to join common hepatic duct. This type gives a short hepaticus and long common bile duct, this type was observed to be more common. In 18% of cases low level of union and in 1.5% of cases high level of union was noted.

In the present study, normal level of union of cystic duct with common hepatic duct was visualised in 75% (30) of cases, high level of union of cystic duct with common hepatic duct was observed in 25% (10) of cases, and low level of union was not noted in any dissection specimens.

Hence the present study coincides with that of Hossein Mahour in terms of normal level of union but not regarding high and of low level of union.

The level of union, high or low insertion of cystic duct carries significant, because of the potential for injury in biliary surgery[47].

III. Length of individual ducts :

Hollinshead (1954), stated, the length of cysticduct as 2.5 - 7.5 cm.

The length of common hepatic duct as 2.5 - 7.5 cms

The length of common bile duct as 5 - 15 cms

Edward V. Johnston (1952) by measuring 35 specimens, gave the length of cystic duct as 2.9 cm; and length and common bile duct as 6.6 cms.

Listenstein and Ivy (1952), reported that in 55% the cystic duct length is 2 - 4 cms; in 20% it is < 2 cm and in 25% it is 4 cm.

The latest edition of gray's anatomy (2005), mentioned the average length of cystic duct is 3 - 4 cm, length of common hepatic duct is 3 cm and the length of common bile duct is 7.5 cms.

Present study (2006),

The average length of cystic duct was 2 - 4 cms.

The average length of common hepatic duct was 2 - 3 cms.

The average length of common bile duct was 5 - 8 cms.

Thus the present study coincides with that Gray and with that of Listenstein and Ivy in terms of cystic duct length and does not correlate with Hollinshead's study.

Clinical Significance :

The clinical significance of the measurement of individual duct length is that during laparoscopic cholecystectomy, the length of the ducts is measured, in order to avoid injuries to the ductal system[32]. Moreover the length of the individual ducts also signifies the level of union of cystic duct with common hepatic duct to note, either high level or low level of union which is at risk of injury during cholecystectomy. Failure to ligate the cystic duct at its correct point mainly 1 - 2 cms proximal to its junction with common hepatic duct and common bile duct leads to tenting of common bile duct pinching of its wall by the ligation[17].

IV. Course and arrangement of structures in hepatoduodenal ligament :

The arrangements of structures in hepatoduodenal ligament described by Hollinshead is common bile duct lies anterior and to the right. The hepatic artery lies anterior just to the left of common bile duct. The portal vein lies behind the duct and artery usually larger and to the left of the duct.

He also mentioned that not more than 1/3 of liver shows the so called normal arrangement, remaining 2/3 presents with variation from this and many of them carries direct surgical importance.

In present study, the arrangement of structures was observed to be the same as mentioned by Hollinshead except in 2.5% of cases in which the common bile duct lies anterior and to the right in the actual edge of hepatoduodenal ligament. The hepatic artery lies anterior just to the left of common bile duct. The portal vein lies behind the duct and artery and to the right of duct.

The **SURGICAL IMPORTANCE** of the structures in hepatoduodenal ligament was given by Mcgregor. He described it as "PRINGLE'S MANOEVRE". The vessels in the free border of the lesser omentum may be controlled by compression between the thumb and index finger of the left hand. This measure is an emergency one which may be useful in cases of injury to one of the large vessels in the area or in hepatic injuries. It is safe for 30 minutes if BP is normal[45].

V. Variations in ductal system :

The variations in ductal system can be discussed under the following headings.

1. Presence of accessory hepatic or cystic ducts
2. Mode of termination of accessory hepatic or cystic ducts

1. Presence of accessory hepatic or cystic ducts :

Schachner (1916) studied 76 specimens in that he noted, double cystic duct in 2 cases, absence of common bile duct in 1 case.

In present study, accessory cystic duct (Double cystic duct) was noted in 2 specimens and in 1 specimen, the cystic duct is long opening directly into the 2nd part of duodenum and a small common hepatic duct opening in the cystic duct close to the neck of gall bladder.

Hence, I found my observations correlated with that of Schachner.

Flint (1922 - 23) described about 29 (14.5%) accessory bile ducts by dissecting 200 specimens. All were accessory right hepatic ducts.

Gray (1936) stated that accessory hepatic ducts are more common from right lobe of liver.

Lurje (1937) reported by studying 194 cadavers in which 2.8% of accessory ducts emerged from right side of liver.

Edward H. Daseler (1947) worked on 500 cases and visualised, accessory right hepatic duct in 8 cases (1.6%).

In this study (2006), I observed in 17.5% (8 cases) accessory hepatic ducts issuing from the right lobe of liver.

On comparing the above studies the present study coincides with that of Flint, Gray, Lurje and Edward regarding the presence of accessory right hepatic duct. Also, it agrees with that of Flint in terms of frequency of occurrence.

Edward H. Daseler (1947) in his study on 500 cases, also reported about small accessory hepatic duct from quadrate lobe of liver in 0.4% (2) of cases.

In present study (2006), a small accessory hepatic duct emerging from the quadrate lobe of liver was observed in 2.2% (1) of cases.

Thus this study correlates with that of Edward Daseler study but showed higher number regarding the accessory duct from quadrate lobe of liver.

2. Mode of termination of duct :

Flint (1922 - 23) dissected 200 specimens. He classified 29 accessory bile ducts on the basis of termination as :

	Flint Study	**Present study**

Junction occurs in upper ½ of common hepatic duct (or) in right hepatic duct - High Union	4.5%	5%
Junction occurs in lower ½ of common hepatic duct	4.5%	5%
Junction at the union of cystic and common hepatic duct	5%	Nil

The present study coincides with the above study except in termination at the union of cystic and common hepatic duct, but I have also encounted accessory right hepatic duct draining in the middle of common hepatic in 5% of cases.

Lurje (1937) stated that 2.8% of accessory ducts from right lobe of liver entered cystic duct.

In present study, (2006) I noted 2.5% of accessory ducts from right lobe of liver joined cystic duct.

Thus the present study agrees with that of Lurje study.

Edward H. Daseler (1947) in his work on 500 cases showed.

	Daseler Study	**Present study**
accessory right hepatic duct entered common bile duct	0.2%	15%
accessory right hepatic duct entered cystic duct	0.6%	2.5%
small accessory right hepatic duct draining into gall bladder	0.4%	Nil

On comparing the above study, it correlates with that of Edward Daseler study but, the occurence is more in the present study and it disagrees with the finding that accessory right hepatic duct draining into gall bladder.

Clinical Importance :

Practically, all the accidents to the ducts occurs mostly during operation of cholecystectomy. Hence it is necessary for the surgeons to make himself familiar with both the normal and variations of these parts.

Jaundice, biliary fistula, and bile peritonitis with pain and fever will follow iatrogenic injury to the biliary ductal system.

Injury to any part of the extra hepatic biliary tree may result in bile lekage, which leads to bile peritonitis. A small, insidious bile leak is probably a greater danger than leakage from an inadvertently cut major duct, because the small leak may go undetected. Small bile ducts in the bed of the gall bladder and small accessory hepatic ducts are easily overlooked and cut[46].

VI. Variations in arterial system in relation to the duct system :

The two main arteries related to the duct system are cystic artery and right hepatic artery. These two arteries are discussed under the following headings.

1. Origin of the artery
2. Relation of the artery to common hepatic duct

1a. Origin of cystic artery :

E.R. Flint (1922 - 23) worked on 200 subjects and found the origin of cystic artery from right hepatic artery in 98% cases, from left hepatic artery in 1.5% and from gastroduodenal in 0.5%.

In present study, I have noted cystic artery arising from right hepatic artery in 92.5%. I have not noted any origin from left hepatic artery and gastroduodenal artery.

	Flint Study	Present study
Origin from right hepatic artery	98%	92.5%
Origin from left hepatic artery	1.5%	Nil
Origin from gastroduodenal artery	0.5%	Nil

The present study coincides with Flint's finding except for cystic artery origin from left hepatic artery and gastroduodenal artery.

Edward H. Daseler M.D., (1947) from a study of 500 specimens, classified the various origins of cystic artery into 12 types.

		Daseler Study	Present Study
Type - I	Cystic artery arising from coeliac right hepatic artery.	58.6%	90%
Type - II	Cystic artery from the proximal portion of the right hepatic artery.	13.1%	5%
Type - III	Cystic artery from an aberrant right hepatic artery derived from superior mesenteric artery.	11.9%	2.5%
Type - IV	Cystic artery from Left hepatic artery.	6.2%	Nil
Type - V	Cystic artery from a branch of common hepatic artery.	2.8%	2.5%
Type - VI	Cystic artery from gastroduodenal.	2.6%	Nil
Type - VII	Cystic artery arises from a branch of coeliac axis.	0.4%	Nil
Type - VIII	Cystic artery derived from replacing or accessory type of right hepatic artery the latter from a source other than superior mesenteric artery.	0.6%	Nil
Type - IX	long slender cystic artery from first portion of superior mesenteric artery.	0.2%	Nil
Type - X	Cystic artery origin from superior pancreaticoduodenal artery.	0.2%	Nil
Type - XI	Cystic artery directly from aorta.	0%	Nil
Type - XII	Cystic artery from a branch of right gastro epiploic artery.	0%	Nil

In the present study, the occurence of cystic artery arising from coeliac right hepatic artery is 90% of specimens in contrast with 58.6% of the author's study which is significantly more. At the same time the origin of cystic artery from proximal portion of right hepatic artery, from aberrant right hepatic artery, from superior mesenteric artery and origin from left hepatic artery are observed in present study, but the occurence is found to be less in number. Various other origins as mentioned by the author are not encountered in this study. But I have noted cystic artery arising from replacing type of right hepatic artery derived from superior mesenteric artery.

Nicholas A. Michels (1951) dissected 200 cadavers and mentioned single cystic artery arising from right hepatic artery in 75% of cases; aberrant right hepatic from a replaced right hepatic derived from superior mesentric artery in 12% of cases; and cystic artery arising from accessory right hepatic derived from superior mesenteric artery in 1.5% of cases.

Hollinshead (1954) also described that cystic artery arises from right hepatic artery. He also added it may also arise from left hepatic artery and common hepatic artery.

In Latest edition of Gray's anatomy (2005), its mentioned that cystic artery arising from right hepatic artery. He also stated that cystic artery may arise some times from common hepatic artery, left hepatic artery and gastroduodenal artery.

The present study (2006) agrees with that of Nicholas regarding the aberrant origin of cystic artery except in the frequency of occurence.

But, on comparing all the above studies including the present study, cystic artery arising from right hepatic artery is noted to be the commonest one. More over, in present study cystic artery arises from coeliac right hepatic artery in 92.5% of cases and from other sources in 7.5% of cases.

b. Accessory cystic artery :

Flint (1922 - 23) studied 200 specimens and observed accessory cystic artery in 31 cases in that in 51.6% (16) of cases it arise from right hepatic artery, in 9.6% (3) cases from common hepatic artery, 35.4% (11) from gastroduodenal artery and 3.2% (1) from superior pancreaticoduodenal artery.

Edward H. Daseler (1947) worked in 580 lab specimens and noted in 65 specimens, accessory cystic artery. In this, in 76.9% cases it arises from right hepatic artery, 6.15% cases from common hepatic artery and 3% cases from accessory right hepatic branch of superior mesenteric artery.

Gray's Anatomy (2005) also mentioned that accessory cystic artery arising from common hepatic artery.

In present study (2006), I have noted accessory cystic artery in 2.5% of cases from a study on 40 specimens in which it arises from common hepatic artery.

In present study, I observed accessory cystic artery arising from common hepatic artery and accessory right hepatic branch of superior mesenteric artery as mentioned by Flint, Edward Daseler and Gray, but I did not encounter other origins of accessory cystic artery as mentioned by them.

c. Double cystic artery :

The presence of double cystic artery observed in the present study was 2.5%. This observation of double cystic artery were compared with that of eminent workers, who worked previously in this field.

Double cystic artery

Flint (1922 - 23)	15%
Edward H. Daseler (1947)	14%
Nicholas (1951)	25%
Paul Sugerbacker (1985)	2 cases from a clinical study
Present study (2006)	2.5%

The occurrence of double cystic artery was found to be less in incidence when compared to the other workers in the present study.

d. Origin of right hepatic artery :

Flint (1922 - 23) from his work on 200 specimens showed, right hepatic artery arising from

	Flint Study	Present Study
main hepatic artery	79%	95%
from superior mesenteric artery	21%	2.5%
presence of 2 right hepatic arteries one from hepatic proper and other from superior mesenteric artery	3.5%	2.5%
presence of 2 right hepatic arteries both from hepatic proper	0.5%	Nil

Present study coincides with that of Flint in origin of right hepatic artery but, contradictory in the presence of 2 right hepatic arteries arising from hepatic proper itself.

Edward H. Daseler (1947) dissected 500 specimens and reported, right hepatic artery arising from

	Daseler Study	Present Study
hepatic artery proper	83.2%	95%

replacing type of right hepatic artery from superior mesenteric artery	11.2%	2.5%
accessory right hepatic artery from superior mesenteric artery	3%	2.5%

Both the studies coincides, except that right hepatic artery origin from replacing type of right hepatic artery derived from superior mesenteric artery which showed less in occurence.

Nicholas (1951) in 200 specimens showed,

	Nicholas Study	**Present Study**
aberrant right hepaticus in that,	26%	4.4%
replaced right hepatic artery	18%	2.2%
accessory right hepatic artery	8%	2.2%

The present study has same findings regarding the aberrant right hepatic artery but disagrees in the frequency of occurrence, which showed lesser number.

Hence, on comparing all the above studies including the present study I observed right hepatic artery arising from hepatic proper is the commonest one.

High Origin of the arteries :

Edward H. Daseler (1947) in his study on 500 specimens mentioned that in 0.34% cases cystic artery arises from right hepatic artery close the portal fissure as a high point.

In the present study, I observed in 5% of specimens cystic artery arising from right hepatic artery close the portal fissure as a high point. Both the cystic artery and right hepatic artery were seen at a higher level close to porto hepatis.

2. Relationship of arteries to common hepatic duct :

a. Cystic artery in relation to common hepatic duct :

Eisendrath (1918) studied about 100 specimens. He described,

	Eisendrath Study	**Present Study**
cystic artery passing ventral to common hepatic duct	27%	7.5%
cystic artery passing dorsal to common hepatic duct	73%	92.5%

In both the studies artery passing dorsal to common hepatic duct is found to be high in number.

Flint (1922 - 23) dissected 200 specimens and stated,

	Flint Study	**Present Study**
cystic artery passing infront of common hepatic duct	16%	7.5%
cystic artery passing behind common hepatic duct	84%	92.5%

The present study correlates with that of Flint study.

Edward H. Daseler (1947) observed 580 laboratory specimens and described.

	Edward Study	**Present Study**
cystic artery crossing anterior to common hepatic duct	21.2%	7.5%
cystic artery crossing posterior to common hepatic duct	2%	92.5%

On comparing the above study the anterior relationship of the artery to common hepatic duct is found to be high in number in the authors study, which is highly contradictory to present study. Since in the present study I encounted posterior relationship to the artery is more as number.

Gray's Anatomy (2005) also mentioned that cystic artery can either pass anterior or posterior to common hepatic duct.

b. Right hepatic artery in relation to common hepatic duct :

Flint (1922 - 23) in his work on 200 specimens showed,

	Flint Study	Present Study
Right hepatic artery passing posterior to common hepatic duct	68%	90%
Right hepatic artery passing anterior to common hepatic duct	12.5%	2.5%

Edward H. Daseler (1947) on 580 cases noted,

	Daseler Study	Present Study
right hepatic artery crossing dorsal to common hepatic duct	65%	90%
right hepatic artery passing ventral to common hepatic duct	11.6%	2.5%
right hepatic artery passing entirely to the left side of duct	1.6%	7.5%

Nicholas A. Michels (1951) statistically estimated in 200 bodies and mentioned,

	Nicholas Study	Present Study
right hepatic artery behind the common hepatic duct	88%	90%
right hepatic artery infront of the common hepatic duct	12%	2.5%

On comparing the above studies, the posterior relationship of right hepatic artery to the common hepatic duct is found to be more in occurrence. Hence present study coincides with Flint, Edward and Nicholas in this aspect.

But the anterior relationship of right hepatic artery with common hepatic duct was observed in 2.5% of cases, which is significantly less in number when compared to the above studies.

Surgical importance :

The degree of variations in the vascular pattern encountered in this area is of vital importance. The increasing number of operations performed for obstructive jaundice and biliary fistula due to man - made injuries of the common bile duct and the hepatic ducts calls for a more detailed knowledge of the blood vessels in gastro hepatic region. Hence identification of major structures in this area before surgery is attempted.

The course of cystic artery is so variable and the occurance of double cystic artery, aberrant cystic artery, replacing cystic arteries is so common, hence careful ligation of the artery is essential. The more frequent damage is that ligation of cystic duct and cystic artery in a single tie leading to severe hemorrhage and necrosis.

Jackson (1938) stated that the major cause of injury to the duct is hemorrhage from a divided cystic artery or an anomalous arterial stump.

The frequency in which the right hepatic artery lies in close approximation to the cystic duct is particularly vulnerable to injury during cholecystectomy. Injuries to these structures may result in trouble some hemorrhage and subsequent injury to common bile ducts or even inadvertent ligation of right hepatic artery, common hepatic artery with resultant hepatic infarction, necrosis and so called `liver death'.

Moreover, the vessels passing anterior to the duct are more important because bile ducts may be injured in efforts to stop hemorrhage from these vessels since they are more prone to include in the clamp along with ducts which in turn leads to severe hemorrhage.

VII. Calot's Trainage :

Hollinshead, described about the boundaries of calot's triangle as cystic duct on rightside, common hepatic duct on the left side and hilum of liver above. The two important vessels noted inside the triangle are cystic artery and right hepatic artery.

Moosman (1948), elaborated the area originally described by calot and now defined as "Moosman's area" in which the following structure lie namely, cystic artery 90%, right hepatic artery 82%, accessory right hepatic artery - 95%, and 23 accessory bile ducts in 91%.

Stremple (1986) estimated that 85% of all variations in the hepatic pedicle are found in this area and 50% of these variations are a potential hazard during cholecystectomy.

In the anatomical basis of clinical practice (2005), it is mentioned that the near triangular space formed between the cystic duct, common hepatic duct and inferior surface of segment V of liver is commonly referred to as calot's triangle.

This space usually contains cystic artery, one or two cystic veins.

He also added that it may contain any accessory ducts which drain into the gall bladder from liver.

In the present study, the boundaries of the calot's triangle was defined 97.5% (39) of cases and in2.5% (1) of cases the boundaries were altered as cystic duct on the left side, common hepatic duct on the right side and hilum of liver above without any situs invertus.

More over in present study, in 85% of cases cystic artery and right hepatic artery are the two main contents, in 15% cases accessory bile ducts were noted in addition to its normal content.

Thus the present study was supported by gray in the presence of accessory bile ducts.

Nicholas (1951) mentioned about double cystic artery with in the calot's triangle in 14.5% of cases in a total of 25% of double cystic artery.

In the present study, I encounter in 2.5% of cases double cystic artery was found inside the calot's triangle.

Thus present study agrees with Nichole's in the concept of double cystic artery inside the calot's triangle though less in occurrence.

Clinical importance:

To avoid misidentification of ducts, identification of cystic duct, cystic artery and the structures to be divided in choleystectomy both open or laparoscopic cholecystectomy, calot's triangle must be dissected and studied moreover, failure to define the normal anatomy and difficult to dissect the calot's triangle results in increased incidence of iatrogenic injury to biliary and portal structures. Biliary leak after cholecystectomy can be avoided by revisiting the biliary anatomy and structures in calot's triangle[47].

Steward L in describing about the biliary duct injuries stated that, class II biliary injuries can be avoided by avoiding working too deep in the triangle of calot[48].

CONCLUSION

The analysis of extrahepaticbiliaryductal system and its related vessels by studying under various methods are concluded as follows.

- Extrahepatic union of right and left hepatic ducts to form the common hepatic duct was noted in 62.5% of cases, which appeared to be more common than intrahepatic union.

- Cystic duct joins the common hepatic duct as angular type of union in 75% of cases.

- Cysticduct joins the common hepatic duct at a point in which it, makes common hepatic duct shorter and common bile duct longer. This is consider as normal level of union.

- The average length of the ducts observed in the study are

  cysticduct 2 - 4 cms, common hepatic duct 2 - 3 cms and common bile duct 5 - 8 cms.

- The arrangement of structures in hepatoduodenal ligament was that, common bile duct lies anterior and to the left of the ligament, hepatic artery lies anterior and to the right of duct system and portal vein larger and posterior to these structures.

- The frequency of occurrence of accessory ducts was 22.5%.

- The most commonly occuring ductal variations is presence of accessory right hepatic ducts terminating any where in common hepatic duct.

- Cystic artery arising from the coeliac right hepatic artery is seen inside the calot's triangle dividing into superficial and deep branches to supply the respective surfaces of gall bladder is noted to be the commonest arrangement.

- Right hepatic artery arises from hepatic proper and seen to the left side of duct system.

- Both cystic and right hepatic arteries passing posterior to the common hepatic duct to reach the calot's triangle is seen to be more common.

Hence, many variations has established in this region and understanding of these variations is undoubtedly responsible for surgeons and radiologist.

Starting from open cholecystectomy to recent advances like **"Living donar liver transplantation with duct to duct anastomosis" (LDLT)**, grading of tumours like **hilar cholangiocarcinoma** and recent investigations like **Magnetic Resonance Cholangiopancreatography (MRCP),** requires definitive knowledge of the anatomy of the ductal system.

Hence, I believe this study is not only pertained to anatomy, but definitely be a useful guideline for operating surgeons and radiologists.

BIBLIOGRAPHY

1. Carrington William M.D., and Arm Stead M. William M.D., Abnormalities of the bile ducts. Ann. Surg 1955; 141 : 598 - 99.

2. Hamilton, Boyd and Mossman. Human Embryology (Prenatal Development of form and function). 1971; 5th edition : Editors : Lambridge W. Heffer & Sons Limited.

3. Skandalakis Surgical Anatomy. The Embryological and Anatomic basis of modern Surgery 2004 ; Vol.2, Editors : John E. Skandalakis.

4. Brewer. Preliminary Report on the Surgical Anatomy of Gallbladder and Duct. Ann. Surg 1900; 29 : 721 - 731.

5. Rugg Ernst. Beitraegezur Chirurgischen Anatomieder Grossen Gallenwege. Arch. f.klin. Chir. 1908 ; 37 : 47-78.

6. Schanchner. Ann. Surg 1916; 64 : 419.

7. Eisendrath. Anamolies of bile ducts and Blood Vessels. J.A.M.A. 1918; 71 : 864.

8. E.R. Flint. Abnormalities in Anatomy of Bile tract. British J. Surg. 1922 - 23; 10 : 509 - 519.

9. McWhorter G.C. A new method of gallbladder dissection with a consideration of the Surgical Anatomy. Surg. Gyn. Obst 1923; 36 : 256 - 263.

10. Beaver M.G. Variations in the extrahepatic biliary tract. Arch. Surg. 1929; 19 : 321 - 326.

11. Thompson J.M. Arteries in the hepatic pedicle, Study in Stastistical human anatomy. Univ. Califo Pub. Anat. 1933; 159 : 555.

12. Henry Gray. Gray's Anatomy Descriptive and applied. 1938 : 27th edition, Editors : T.B.Johnston.

13. A. Lurje M.D., The topography of the Extrahepatic biliary Passages. Ann. Surg. 1937 ; 105 : 161 - 168.

14. S. Danaweeder M.D., Choledochus Cyst with a double common bile duct. Ann. Surg. 1939; 110 : 55.

15. Clyde Everette M.D., and Harold E. Macumber. M.D., Anomalous distribution of the Extrahepatic biliary ducts. Ann. Surg. 1942; 115 : 472 - 473.

16. Paul Campiche M.D., A rare abnormality of the bile ducts. The anteduodenal position of the cystic duct. Ann. Surg. 1944; 119 : 774-776.

17. Edward H. Daseler M.D., Barry J. Anson Ph.D., The cystic artery and constituents of the hepatic pedicle. Surg. Gyne. Obst. 1947 ; 85 : 47 - 63.

18. Milroy Paul. Anomaly of right hepatic duct. British J. Surg. 1948; 35 : 383 - 84.

19. Charles B. Ripstein M.D., and Gavin Miller M.D., Choledochus Cyst. associated with Cong. atresia of the bile ducts. Ann. Surg. 1948; 128: 1173 - 74.

20. Mossman D.A. Structures of the Cysto - hepatic angle encountered in Cholecystectomy. Anat. Rec. 1948; 100 : 698.

21. Nicholas A. Michels M.A., DSC. The hepatic, cystic and retroduodenal arteries and their relations to the biliary ducts. Ann. Surg. 1951; 133 : 503 - 522.

22. Edward V. Johnston M.D., and Barry J. Anson Ph.D., Variations in the formation and vascular relationships of the bile ducts. 1952; 94 : 670 - 685.

23. Henry Hollinshead Ph.D., Anatomy for Surgeon. 1952 ; Vol.2, Editors : Paul B. Hoeber, Inc. Medical Book Dept. of Harper and Brothers.

24. G. Hossein Mahour M.D., The common bile duct in man. Ann. Surg. 1961; 165 : 415 - 419.

25. Deward O. Ferris M.D., Cong absence of gall bladder. Arch. Surg. 1965; 91 : 359 - 360.

26. Levin and Sakenberg. South African J. Surg. 1980; 18 : 23.

27. Paul H. Sugarbaker M.D., Cong duplication of the gall bladder associated with an anomalous right hepatic artery. Ann. Surg. 1985; 149 : 812 - 814.

28. Stremple JF. The need for careful operative dissection in moosmans area during cholecystectomy. http://www.ncbi.nlm:nib:gov/entrez/query.fcgi?cmd= Retrieve & db = pubmed & list_uids = 3738714 & do 12/4/05.

29. The Southern Surgeon Club. A prospective analysis of 1518 laparscopic cholecystectomy. The New England J. Med. 1991; 324 : 1073 - 76.

30. Ricardo L. Ross M.D., Laproscopic injuries to the bile ducts. Arch. Surg. 1992; 127 : 596 - 602.

31. A.R. Mossa M.D., Laparoscopic injuries to the bile ducts. Ann. Surg. 1992; 215 : 203 - 207.

32. Andrew M. Ress M.D., Spectrum and Management of major complications of laparoscopic cholecystectomy. Am. J. Surg. 1993 ; 165: 655 - 659.

33. Juan R. Madariago M.D., F.A.C.S., Corrective treatment and anatomic considerations for laparoscopic Cholecystectomy Injuries. J. Am. College. Surg. 1994; 179 : 321 - 325.

34. L.H. Blumgart. Surgery of the liver and Biliary tract. 1995; 3th edition, Vol.1, Editors : L.H. Blumgart and Y. Fong.

35. Fristcher Ravers. Am. J. Surg. 2000; 66 : 374.

36. Nicholas. Gastrointestinal Endoscopy. 2000; 170 : 119 - 120.

37. Strasberg sm. Avoidance of biliary injuries during laparoscopic cholecystectomy. J. Hepatobiliary Pancreat. Surg.2002; 9(5):543-547. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi? cmd = Retrieve & db = pubmed & dopt = Abstract & list_ui 12/4/05

38. Gastrointestinal Endoscopy. 2003 ; 58 : 646 - 647.

39. M.Hribernik. Variations of Intrahepatic and proximal Extrahepatic bile ducts. Hepatogastroenterology. 2003; 50 : 342 - 348.

40. Sharif K de Ville de Goyet J. Bile duct of Luschka leading to bile leak after cholecystectomy - revisiting the biliary anatomy. J. Pediatr. Surg. 2003; Nov; 38(11) : E21 - 3. http : // www.ncbi.nlm.nih.gov / entrez / query.fcgi? cmd= Retrieve & db = pubmed & dopt = Abstract & list_ui 12/4/05

41. Tomaz Benedik; Principles of Safety in laparoscopic cholecystectomy. http: // www.vestnik.szd.si/st3 - S1ang/St3-S1ang - 03 - 07.htm 12/4/05.

42. Masanori Asanda M.D., Endoscopic retrieval of broken external biliary stends from common bile duct. Gastrointestinal endoscopy. 2003 ; 57 : 611.

43. Kyung - Suk Suh M.D., Biliary reconstruction using the cystic duct in right lobe living donor liver transplantation. Amer. College. Surg. 2004; 60 : 661. doi : 10. 1016 / j. jam coll. surg. 2004. 05. 278.

44. Gray's Anatomy. The anatomical basis of clinical practice. 2005, 39th edition, Editors : Susanstandring.

45. Alexander Lee Mcgregor. A synopsis of surgical anatomy. 1963; 9th edition, Editors : Briston - Johnwright and Sons Ltd.

46. Maingot's Abdominal Operation. 1997 ; 10th edition, Vol.2, Editors : Micheal J. Zinner M.D., Seymour ISchwartz, Harold Ellis.

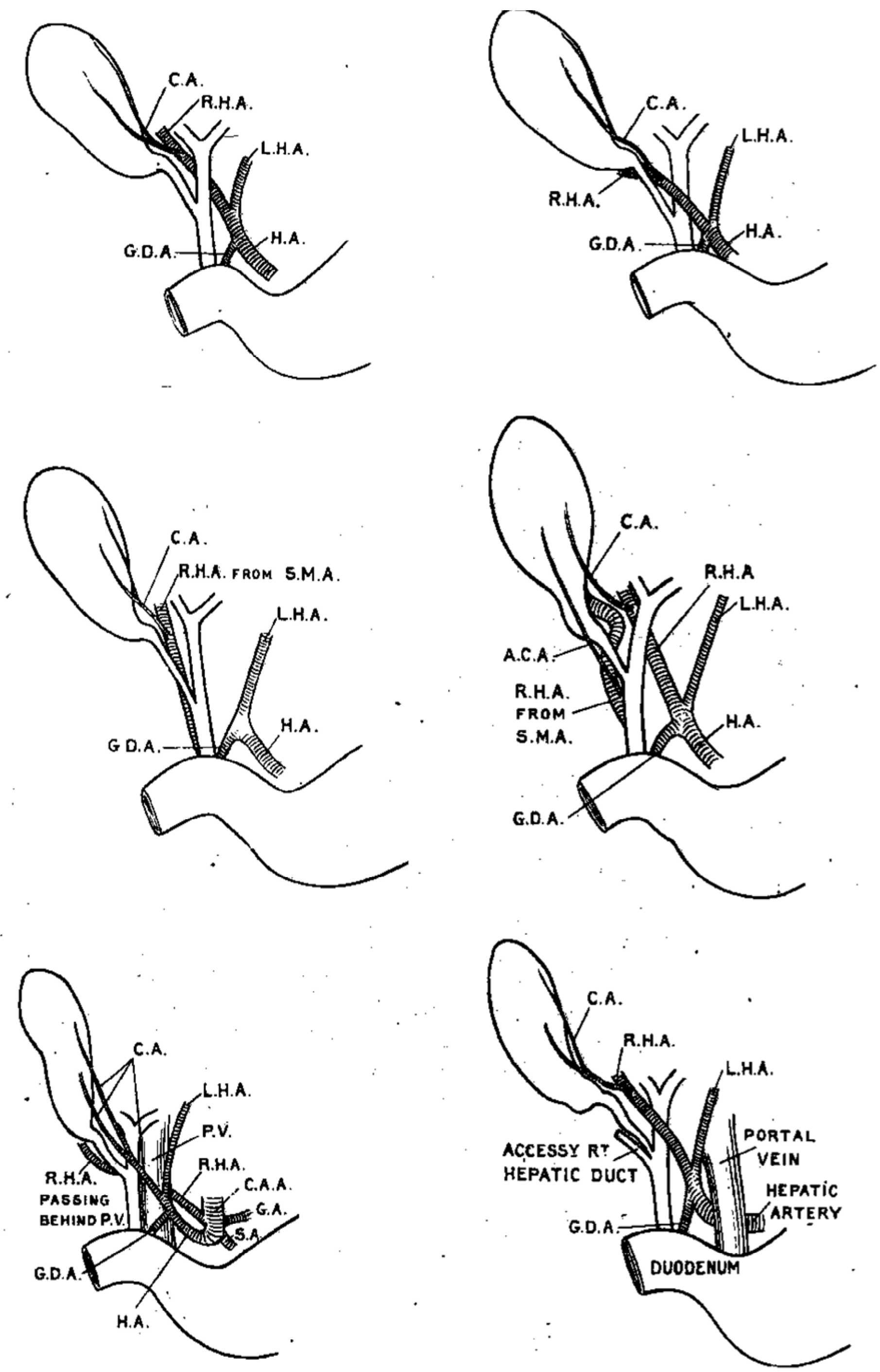
47. Dallo Torre A. Isolated agenesis of gall bladder. http : // www.ncbi. nlm. nih. gov / entrez / query . fcgi? cmd = Retrieve & db = pubmed & dopt = Abstract & list_ui 12/4/05

48. Way LW, Stewart L. Causes and prevention of laparoscopic bile duct injuries : analysis of 252 cases from a human factors and cognitive psychology perspective. http: // www.ncbi.nlm. nih. gov / entrez / query. fcgi? cmd = Retireve & db = pubmed & dopt = Abstract & list_ui 12/4/05

49. Grainger & Allinson's Diagnostic Radiology. Textbook of medical imagining. 1997; Vol.2, 3rd edition, Editors : R.G.Grainger / D.J. Allison.

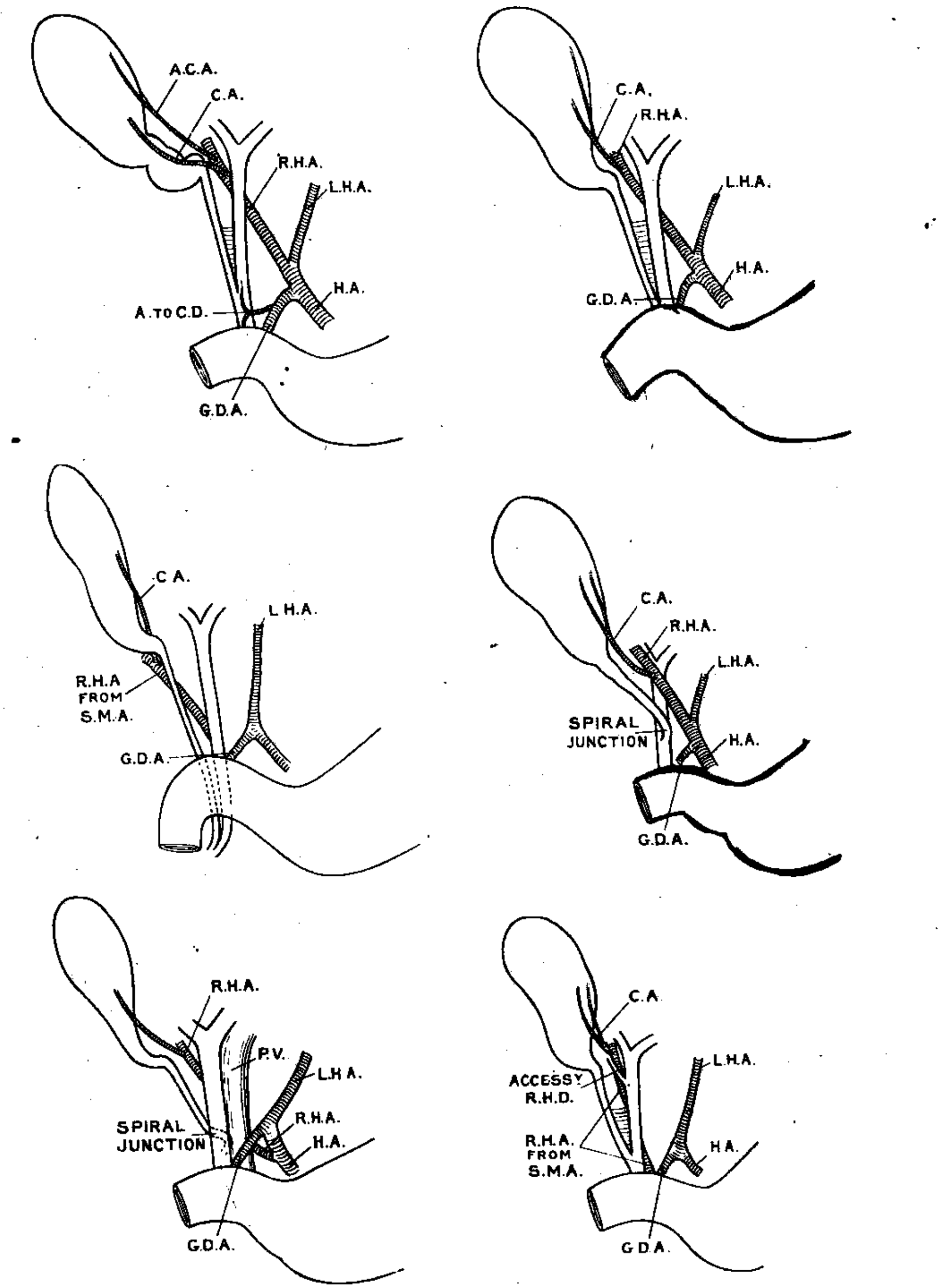
50. G. Scott Gazelle, Sanjaysaini, Peter R. Mueller. Hepatobiliary and Pancreatic Radiology Imaging and Intervention. 1998; Vol.2, Editors. G. Scott Gazelle, Sanjaysaini, Peter R. Mueller.

Pic.1 : Diagrams Illustrating various abnormalities in the arteries and bile-ducts met with in gall - bladder surgery

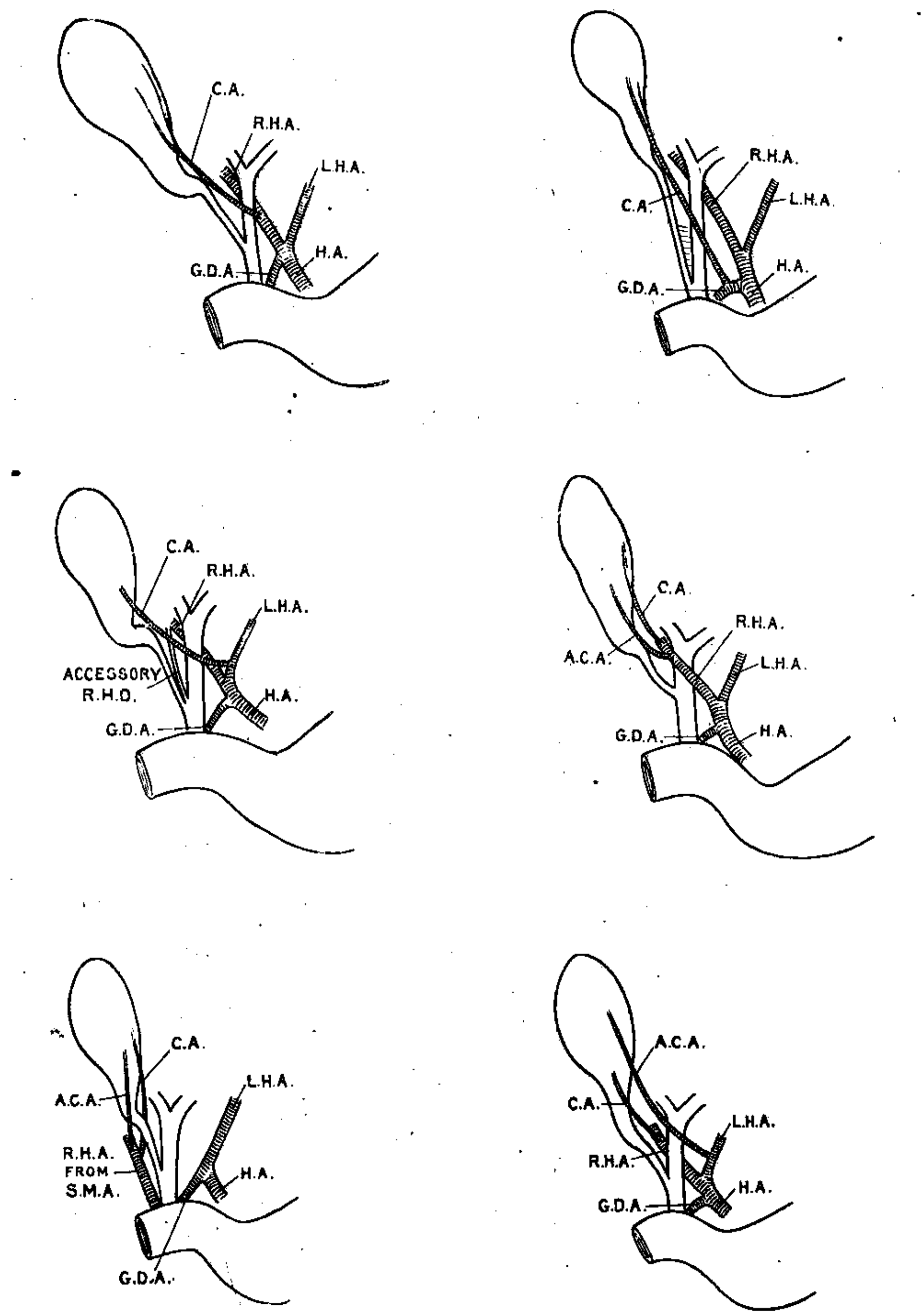


(C.A.) Cystic artery ; (G.D.A.) Gastroduodenal artery (H.A.) Hepatic artery ; (L.H.A.) Left hepatic artery ; (R.H.A.) Right hepatic artery ; (S.M.A.) Superior mesenteric artery ; (A.C.A.) Accessory cystic artery ; (P.V.) Portal vein ; (C.A.A.) Cœliac axis artery ; (G.A.) Gastric artery ; (S.A.) Splenic artery ; (R.H.D.) Right hepatic duct ; (S.P.D.A.) Superior pancreatico-duodenal artery ; (C.D.) Cystic duct.

DIAGRAMS—*continued.*

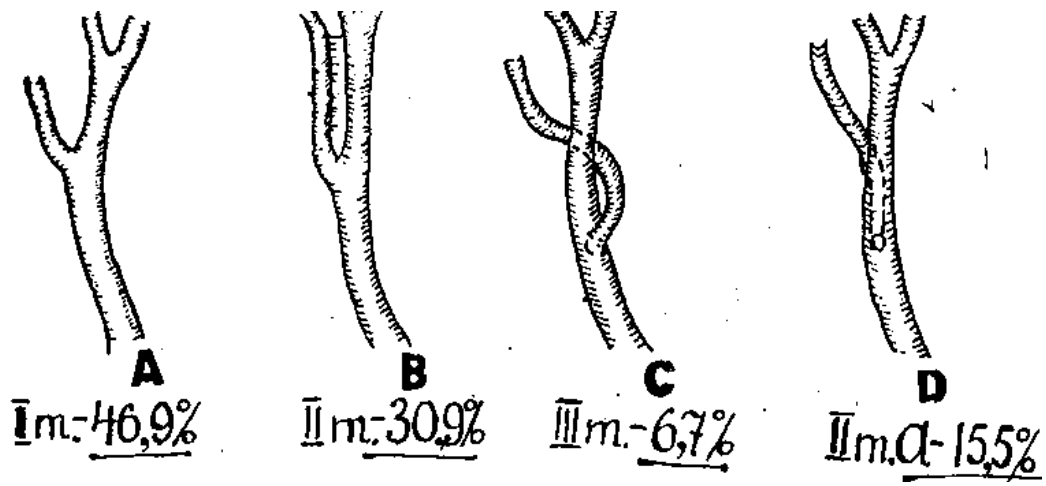


(C.A.) Cystic artery; (G.D.A.) Gastroduodenal artery; (H.A.) Hepatic artery; (L.H.A.) Left hepatic artery; (R.H.A.) Right hepatic artery; (S.M.A.) Superior mesenteric artery; (A.C.A.) Accessory cystic artery; (P.V.) Portal vein; (C.A.A.) Cœliac axis artery; (G.A.) Gastric artery; (S.A.) Splenic artery; (R.H.D.) Right hepatic duct; (S.P.D.A.) Superior pancreatico-duodenal artery; (C.D.) Cystic duct.

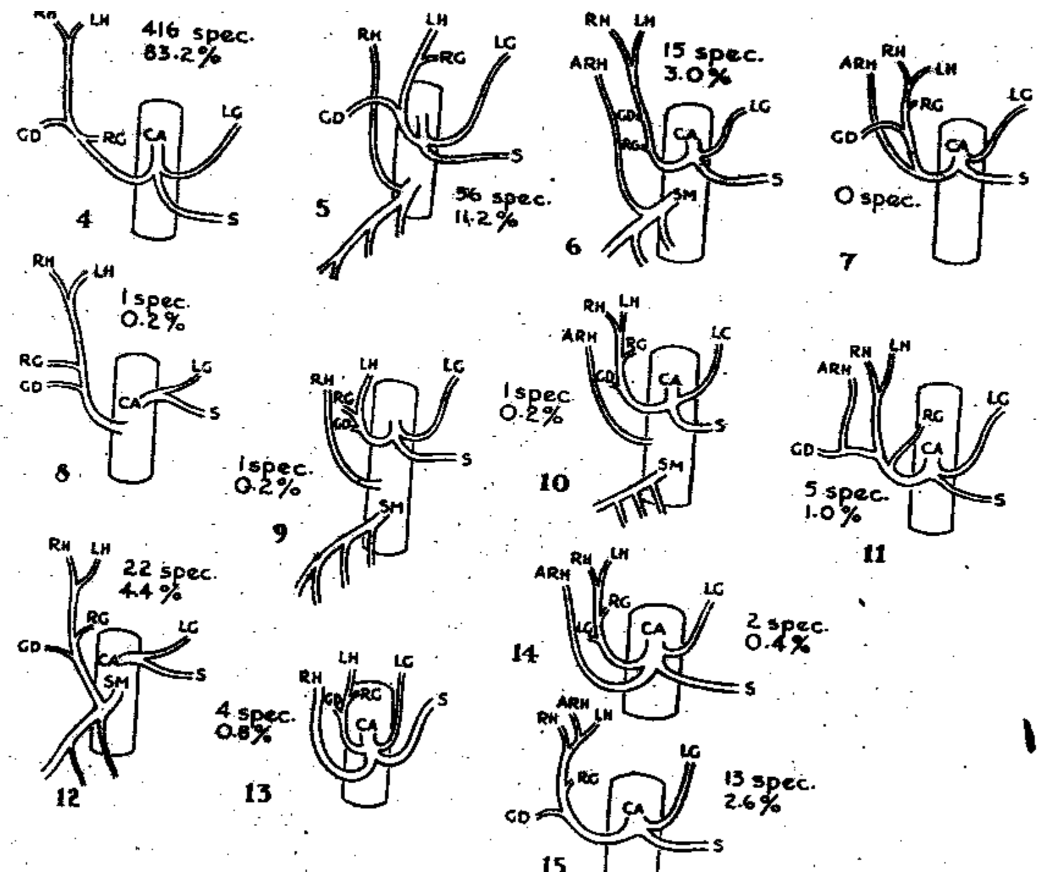


(C.A.) Cystic artery; (G.D.A.) Gastroduodenal artery; (H.A.) Hepatic artery; (L.H.A.) Left hepatic artery; (R.H.A.) Right hepatic artery; (S.M.A.) Superior mesenteric artery; (A.C.A.) Accessory cystic artery; (P.V.) Portal vein; (C.A.A.) Cœliac axis artery; (G.A.) Gastric artery; (S.A.) Splenic artery; (R.H.D.) Right hepatic duct; (S.P.D.A.) Superior pancreatico-duodenal artery; (C.O.) Cystic duct.

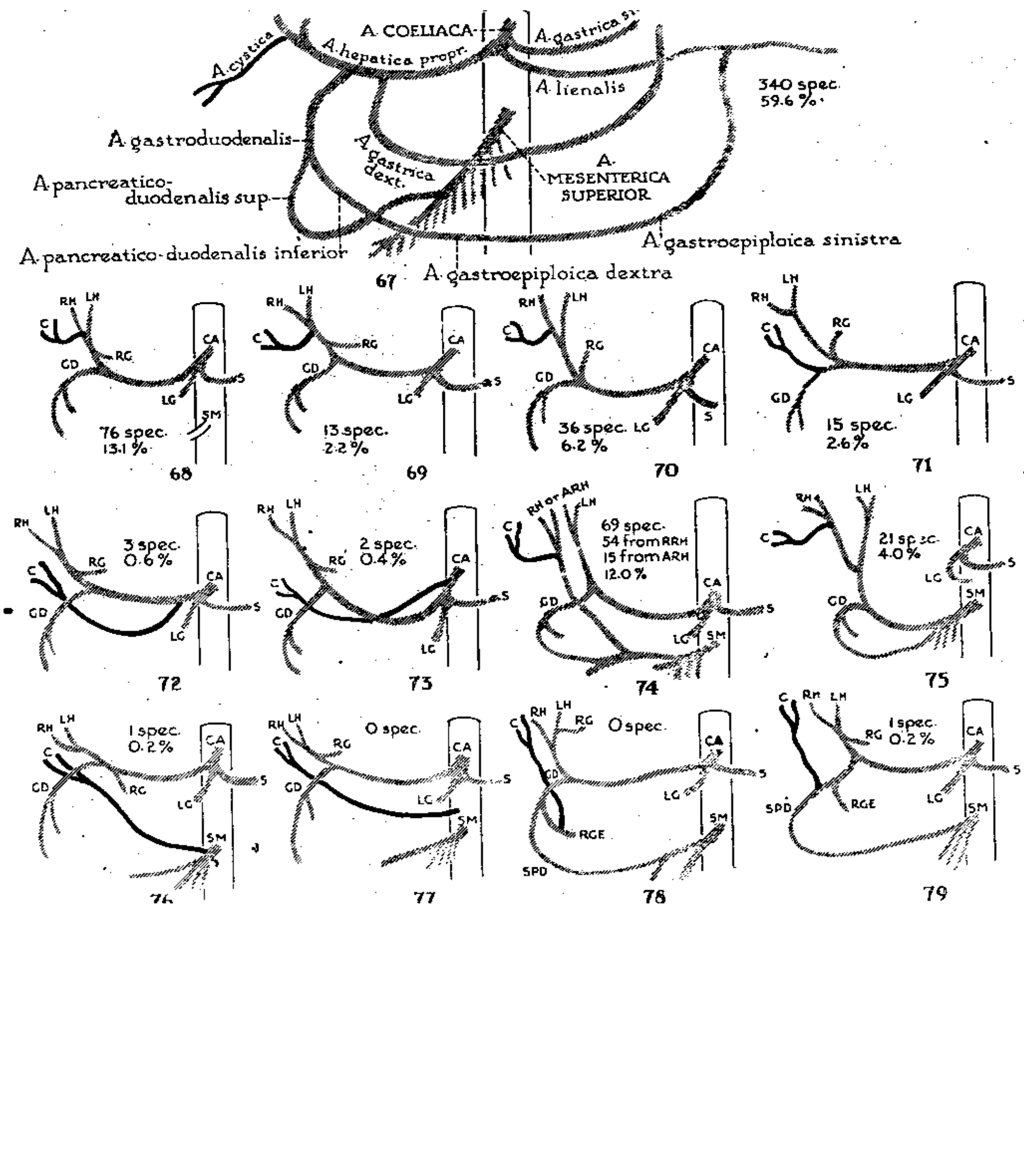
Pic.2: Types of union of cystic and hepatic duct



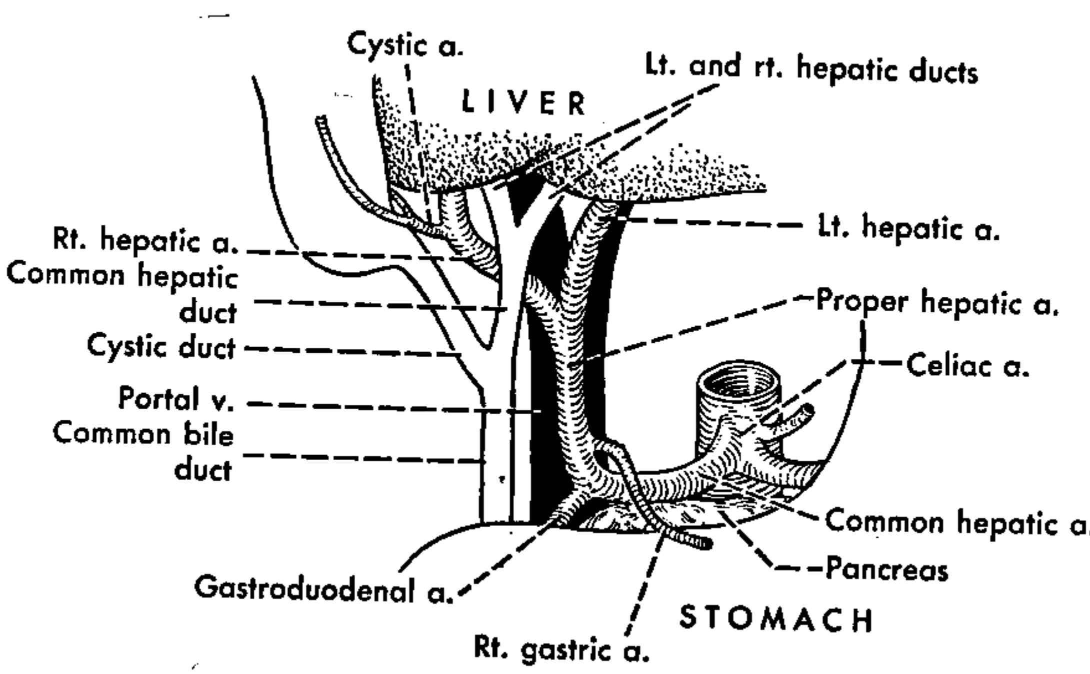
Pic.3 : Right hepatic artery : Variations in origin, diagrammatic



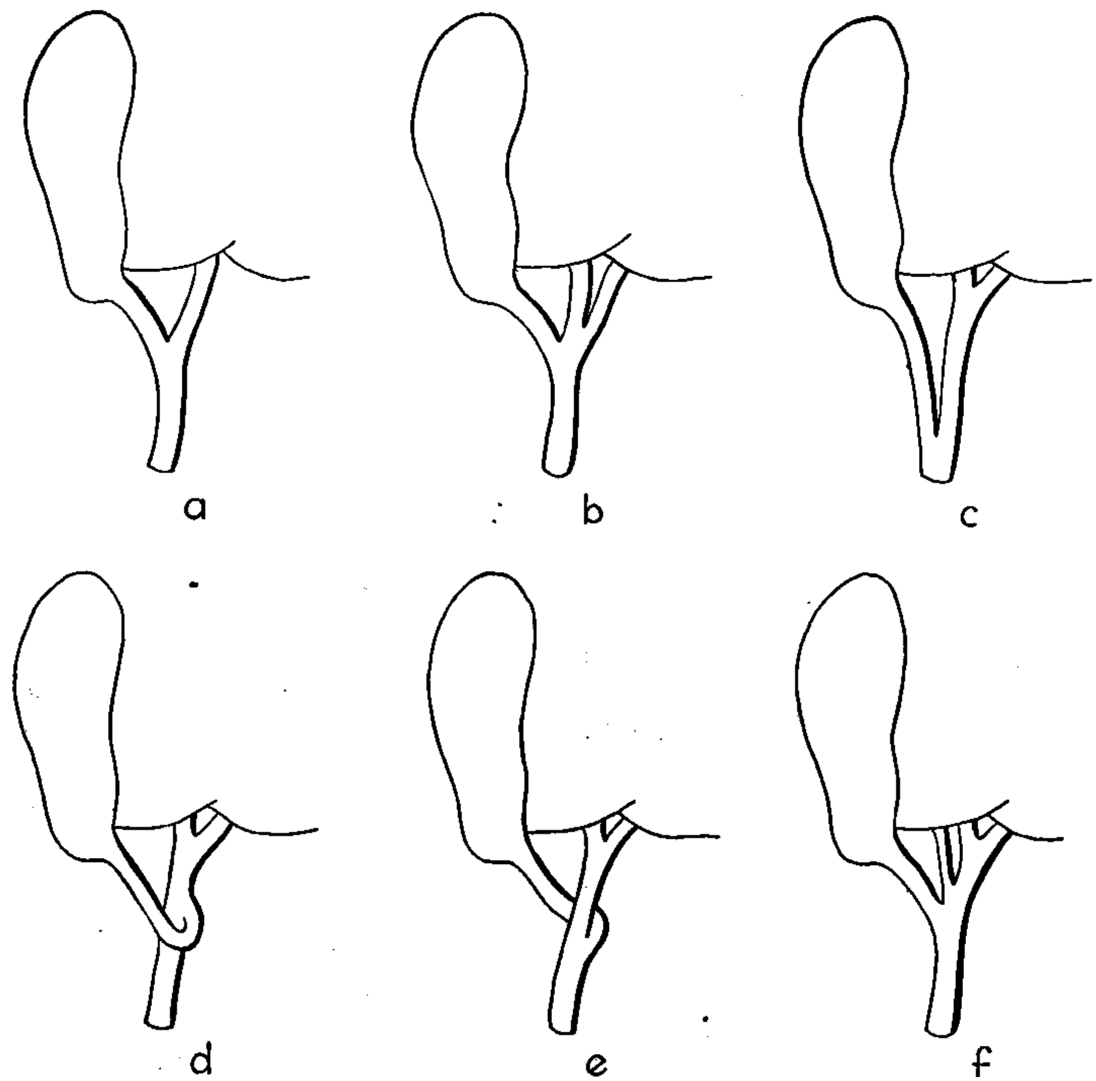
PIC.3a : Cystic Artery : Variations in origin, diagrammatic



Pic.4 : Course and relations of the structures of the hepatic pedicle

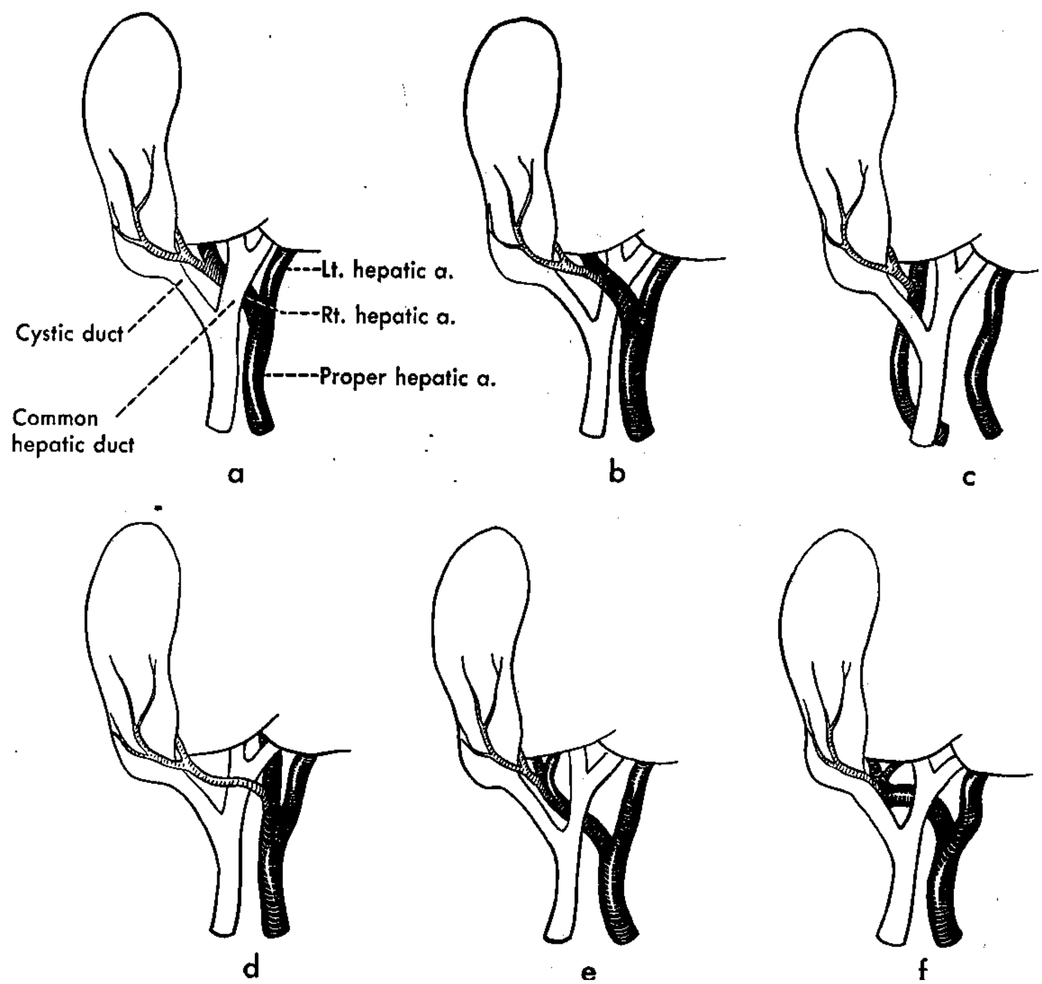


Pic.4a : Variations in the type of union of cystic duct with common hepatic duct.



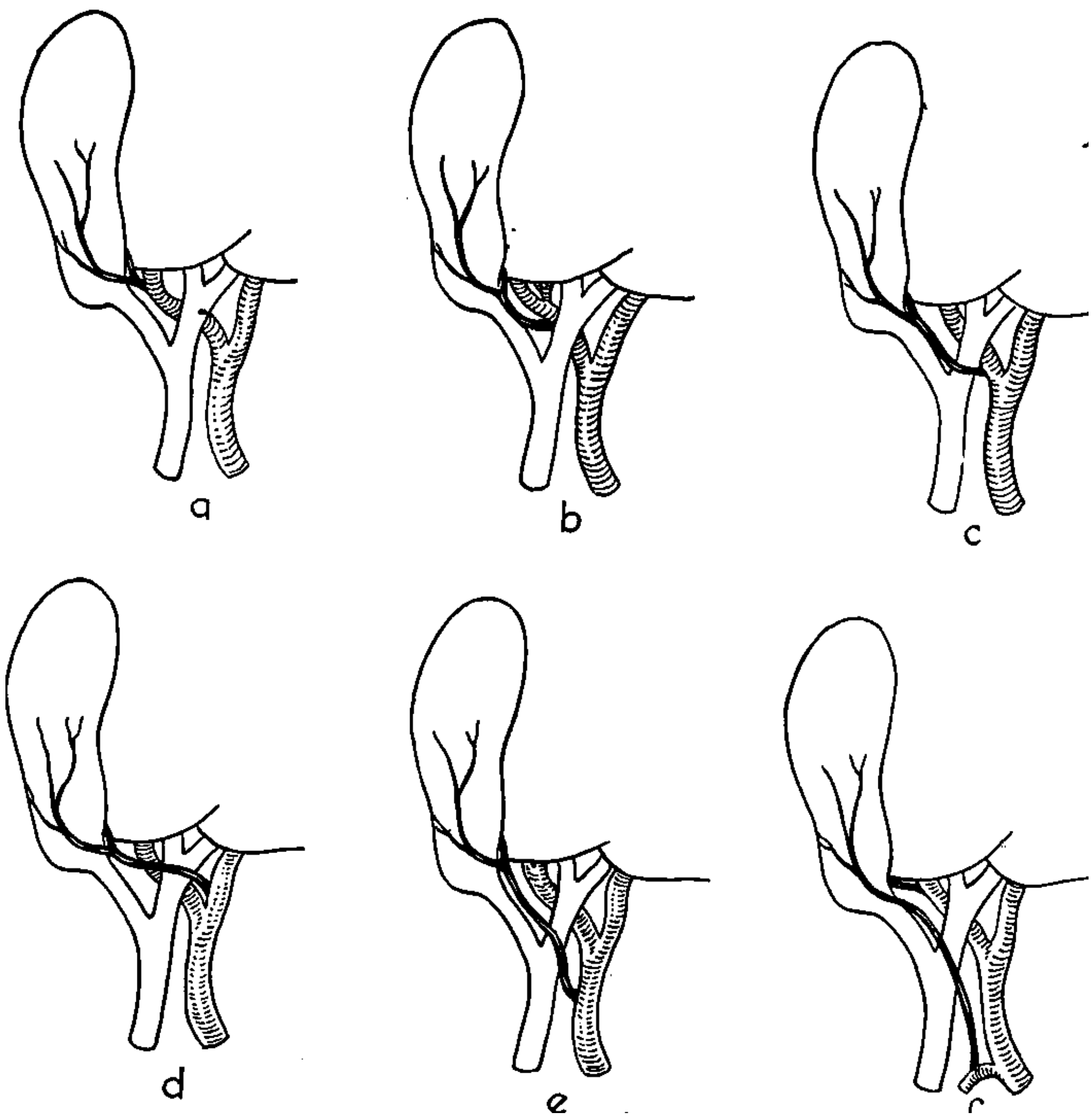
a. intrahepatic, union b. low union of the duct, c. long cystic and common hepatic ducts, paralleling each other d. and e. spiral union f. an accessory hepatic duct joining the common hepatic duct

PIC.4b : Variations in the course and relationship of a right hepatic artery



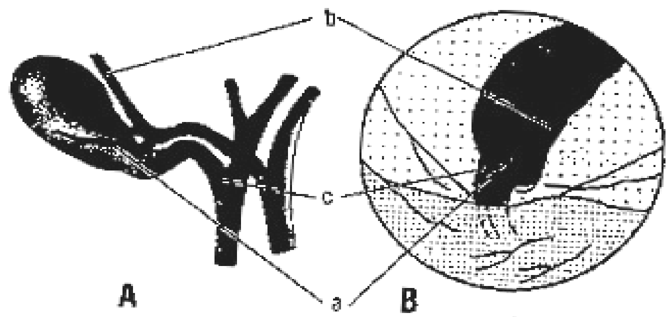
a. normal relations b. the artery crossing anterior to common hepatic duct c. right hepatic artery lying entirely to the right of the common hepatic duct d. entirely to the left of the common hepatic duct e. artery paralleling the cystic duct and f. artery behind the cystic duct.

Pic.4c : Variations in the origin and course of the cystic artery

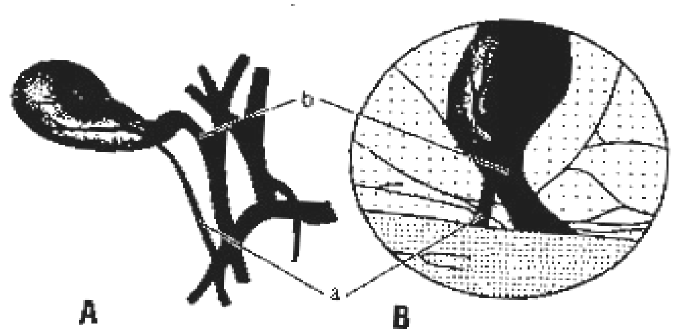


a & b. normal but different courses c. origin from the right hepatic artery outside the triangle, d. origin from the left hepatic artery e. from the common hepatic f. double cystic arteries, of which the superficial branch arises from the gastroduodenal, while the deep branch from the right hepatic.

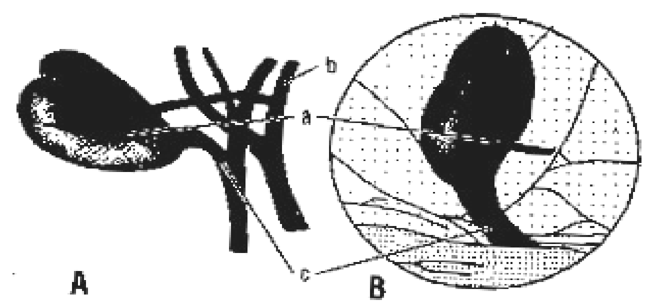
Pic.5



"Large cystic artery." **A**, Conventional visualization. **B**, Laparoscopic visualization. a, Cystic artery (or cystic arteries); b, Aberrant right hepatic artery; c, Cystic duct. (Modified from Balija M, Huis M, Nikolić V, Štulhofer M. Laparoscopic visualization of the cystic artery anatomy. World J Surg 1999;23:703-707 with permission.)



. Cystic artery originating from the gastroduodenal artery. **A**, Conventional visualization. **B**, Laparoscopic visualization. a, Cystic artery; b, Cystic duct. (Modified from Balija M, Huis M, Nikolić V, Štulhofer M. Laparoscopic visualization of the cystic artery anatomy. World J Surg 1999; 23:703-707; with permission.)



. Cystic artery originating from the left hepatic artery. **A**, Conventional visualization. **B**, Laparoscopic visualization. a, Cystic artery originating from the left hepatic artery; b, Left hepatic artery; c, Cystic duct. (Modified from Balija M, Huis M, Nikolić V, Štulhofer M. Laparoscopic visualization of the cystic artery anatomy. World J Surg 1999;23:703-707; with permission.)

TABLE - D

TYPES OF UNION OF CYSTIC DUCT WITH COMMON HEPATIC DUCT

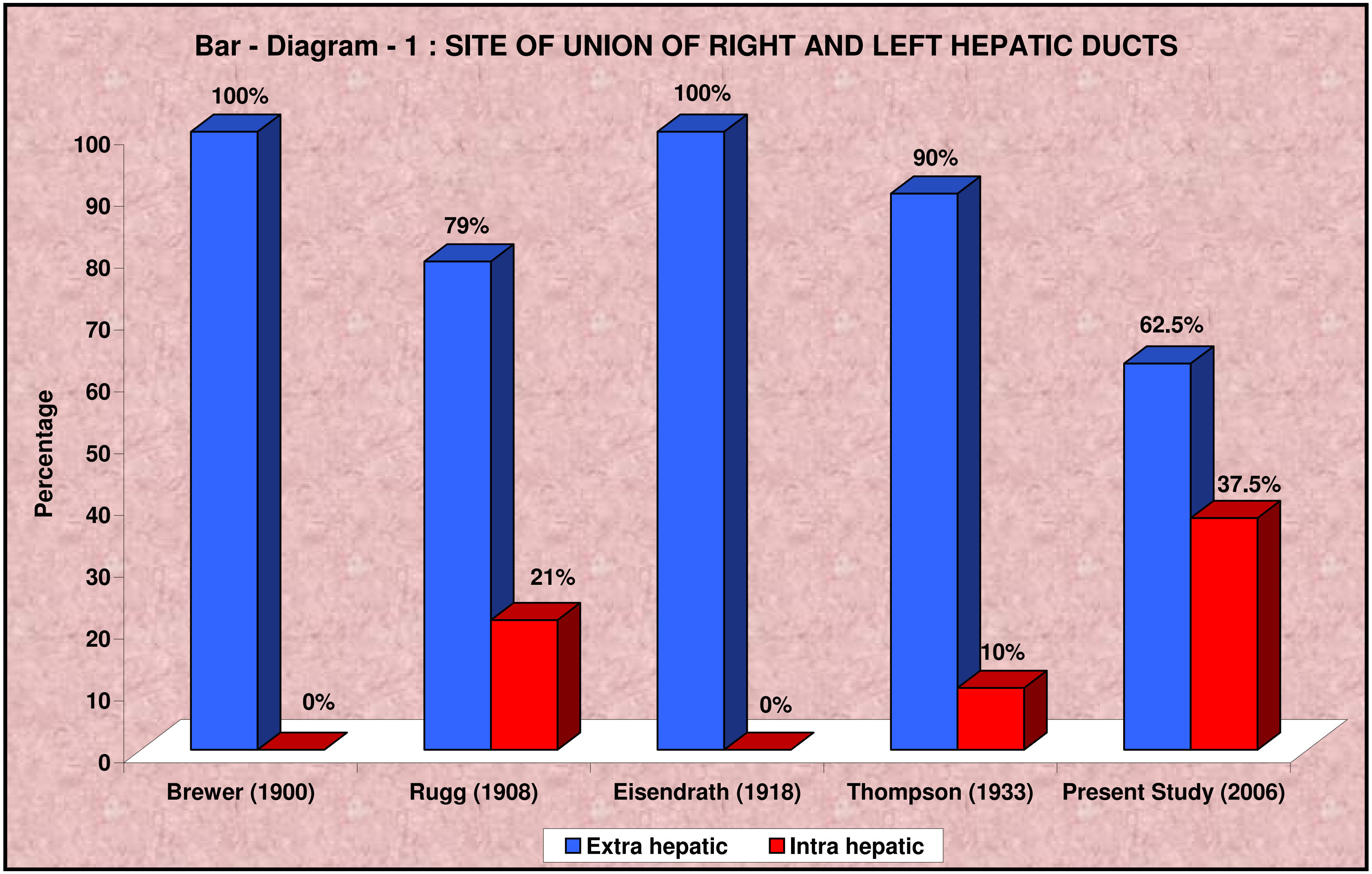
Authors	Angular	Parallel	Spiral
Rugg (1908)	35%	20%	45%
Eisendrath (1918)	75%	17%	8%
Thompson (1933)	90%	6%	4%
A.Lurje (1937)	46.9%	30.9%	22.2%
Edward (1952)	51.4%	31.4%	17.1%
Present Study (2006)	75%	25%	-

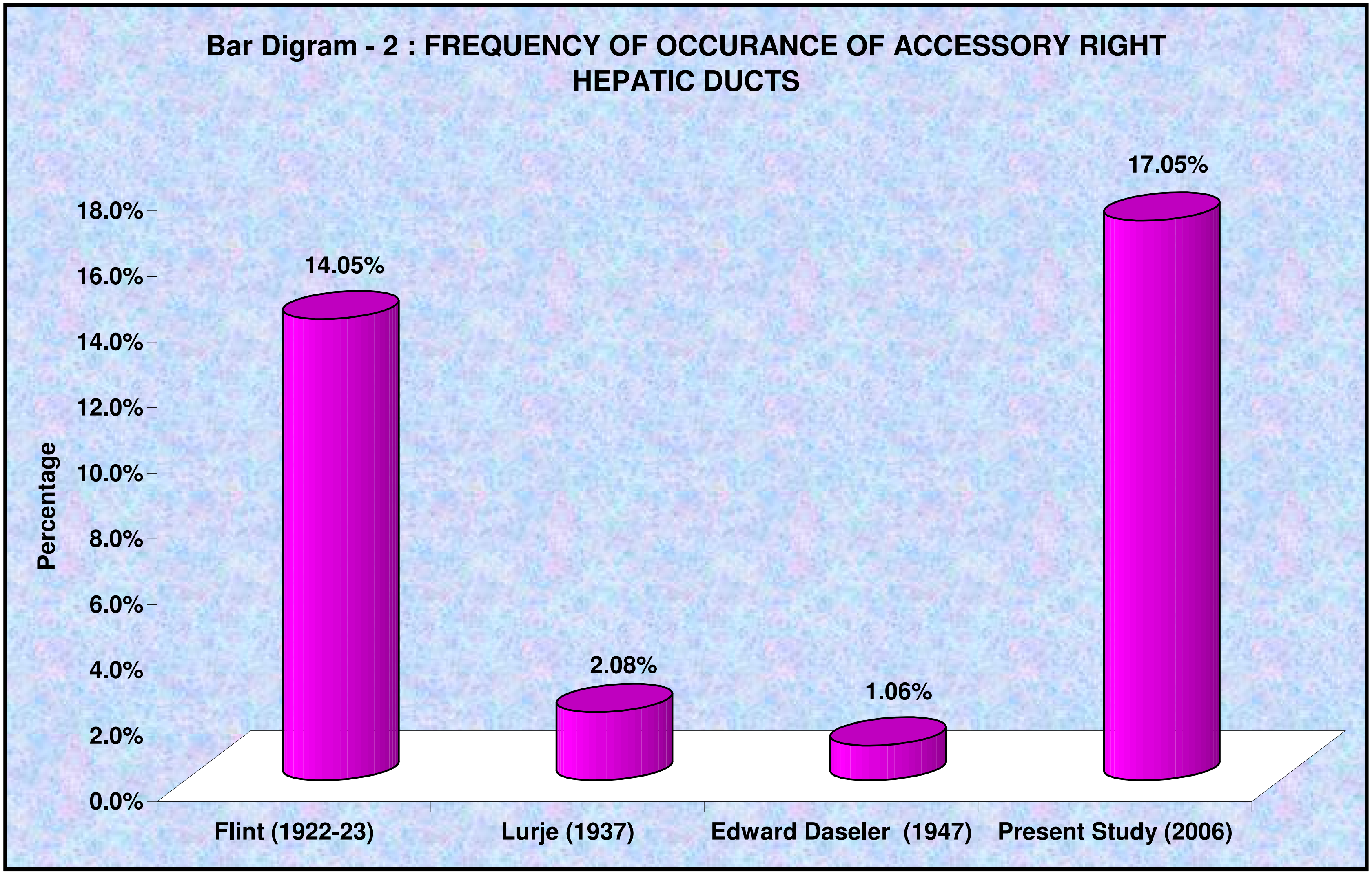
TABLE - A

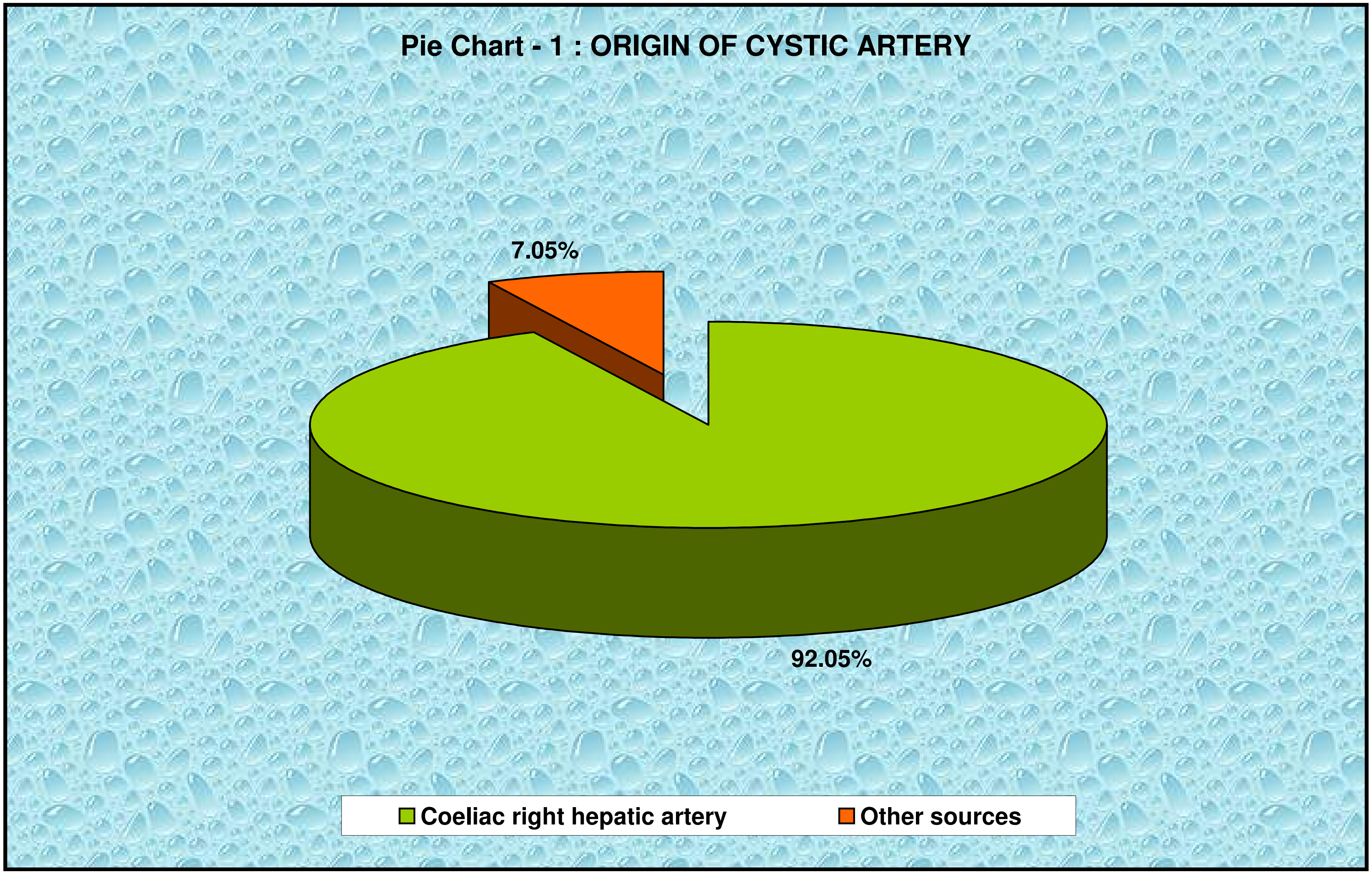
	No. of specimens	Total percentage	Before Separation (cm)	After separation (cm)
Common bile duct excluding parallel junctions	27	19.4	6.6	No difference
Common bile duct in parallel junctions	7	21.6	6.6	4
Combined common bile duct	34	100	6.6	6.1

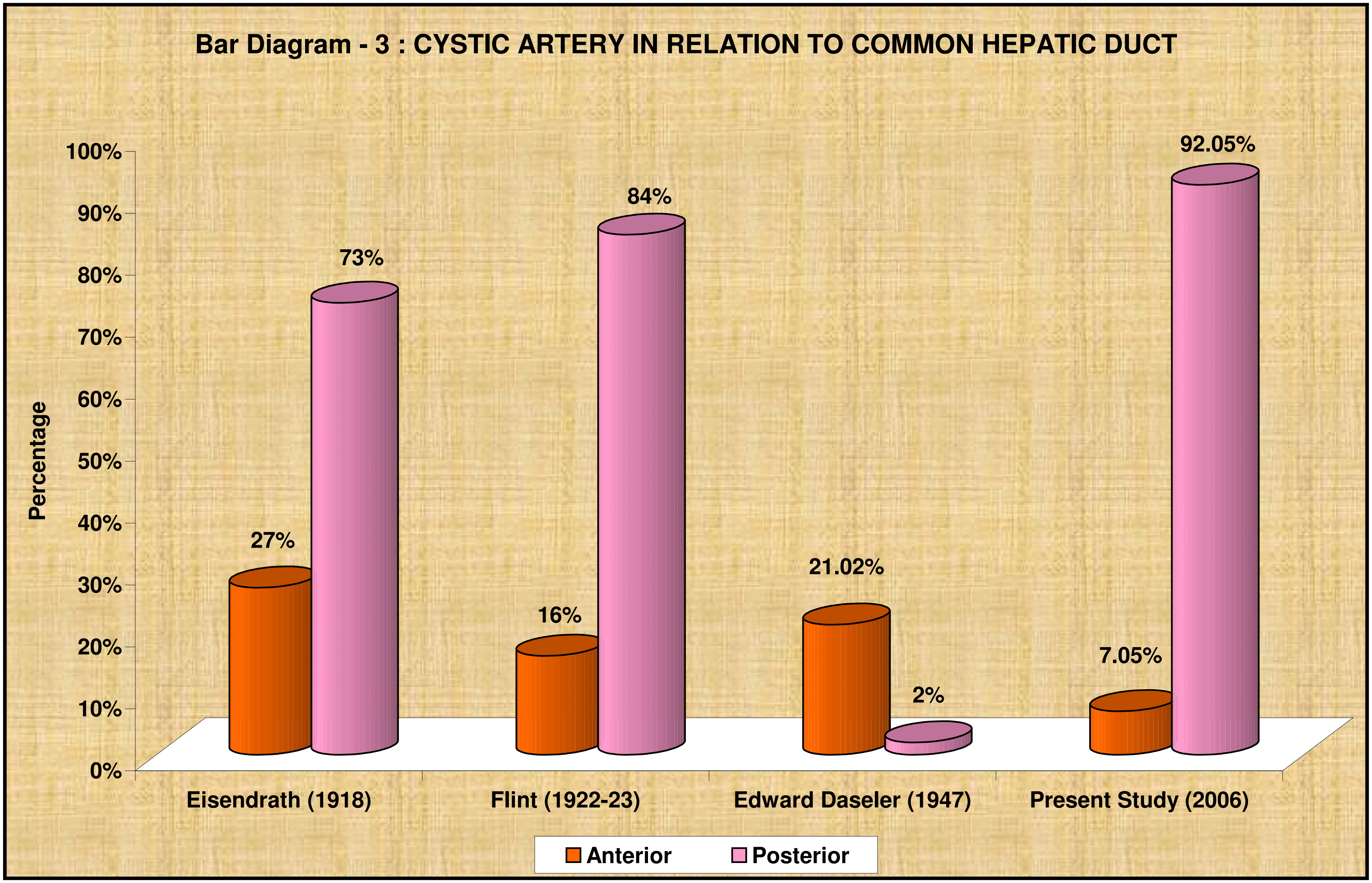
TABLE - B

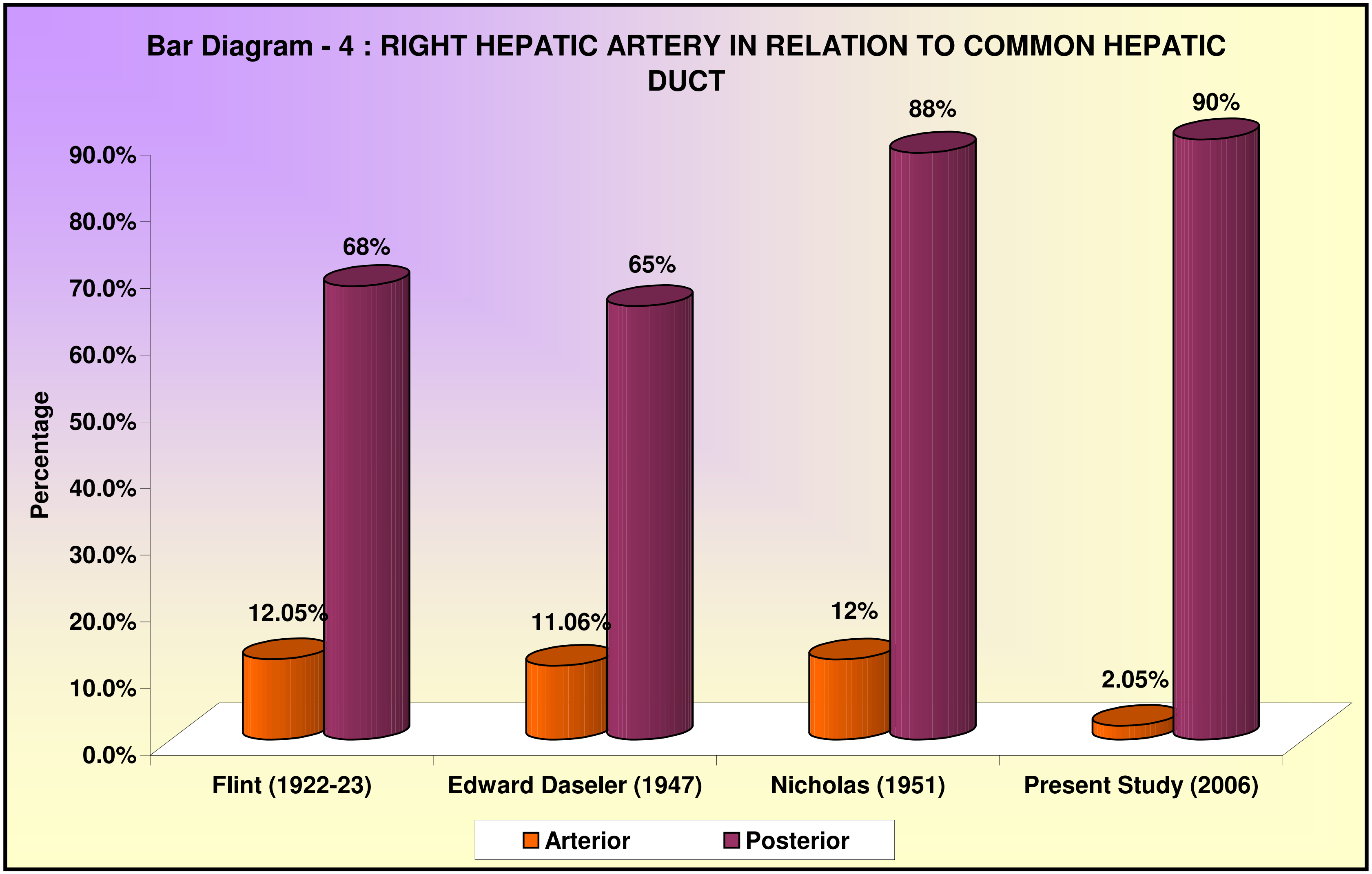
	No. of Specimens	**Total percentage**	**Before separation (cm)**	**After separation (cm)**
Common hepatic duct excluding parallel cystohepatic junctions	26	78.8	2.9	No difference
Common hepatic duct in parallel junctions	7	21.2	2.9	5.2
Combined common hepatic duct	33	100	2.9	3.4

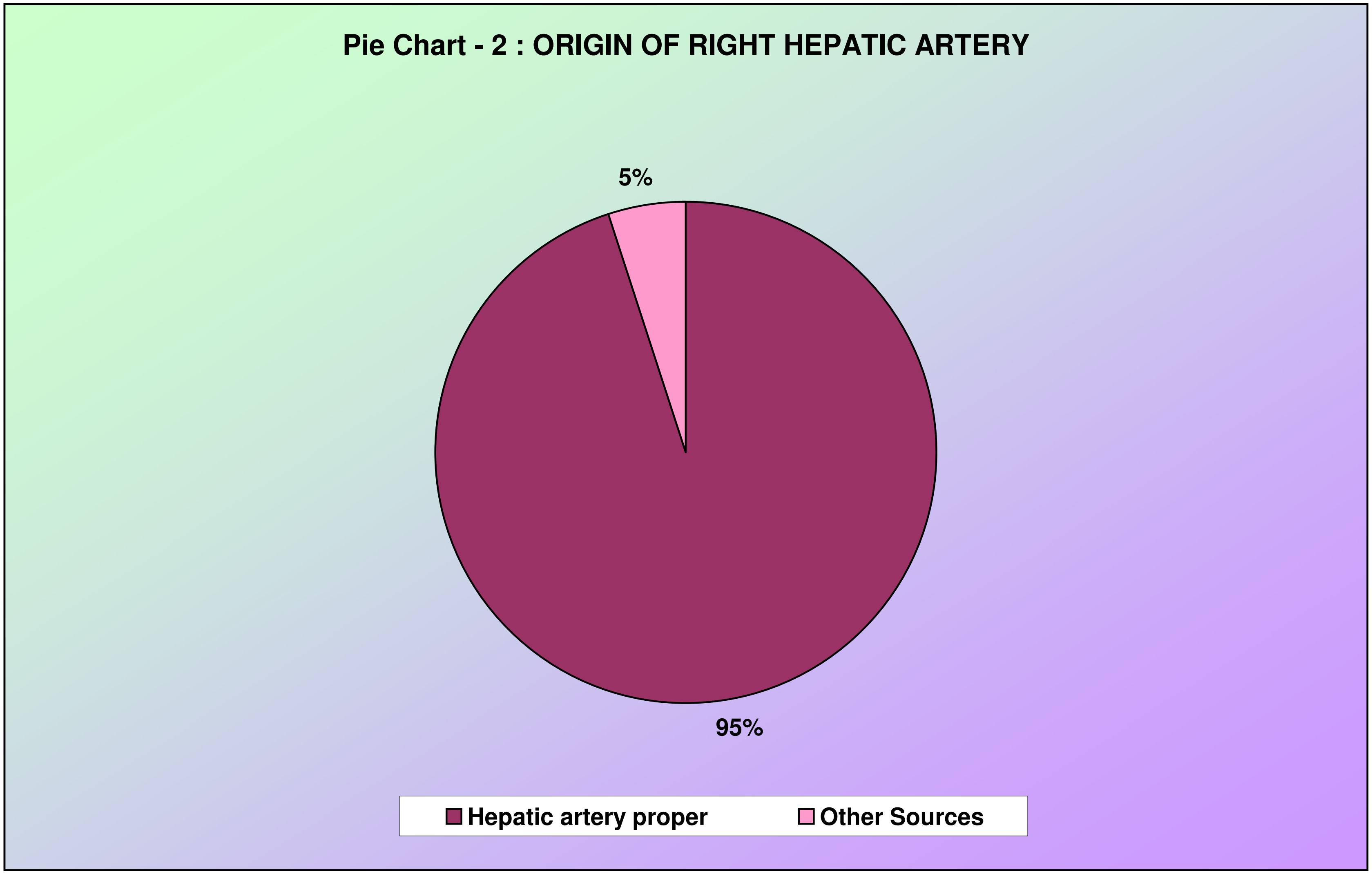

Bar - Diagram - 1 : SITE OF UNION OF RIGHT AND LEFT HEPATIC DUCTS
Percentage
0
10
20
30
40
50
60
70
80
90
100
100%
0%
79%
21%
100%
0%
90%
10%
62.5%
37.5%
Brewer (1900)
Rugg (1908)
Eisendrath (1918)
Thompson (1933)
Present Study (2006)
Extra hepatic
Intra hepatic


Bar Digram - 2 : FREQUENCY OF OCCURANCE OF ACCESSORY RIGHT HEPATIC DUCTS
Percentage
18.0%
16.0%
14.0%
12.0%
10.0%
8.0%
6.0%
4.0%
2.0%
0.0%
14.05%
2.08%
1.06%
17.05%
Flint (1922-23)
Lurje (1937)
Edward Daseler (1947)
Present Study (2006)


Pie Chart - 1 : ORIGIN OF CYSTIC ARTERY
7.05%
92.05%
Coeliac right hepatic artery
Other sources


Bar Diagram - 3 : CYSTIC ARTERY IN RELATION TO COMMON HEPATIC DUCT
Percentage
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
27%
73%
16%
84%
21.02%
2%
7.05%
92.05%
Eisendrath (1918)
Flint (1922-23)
Edward Daseler (1947)
Present Study (2006)
Anterior
Posterior


Bar Diagram - 4 : RIGHT HEPATIC ARTERY IN RELATION TO COMMON HEPATIC DUCT
Percentage
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
12.05%
68%
11.06%
65%
12%
88%
2.05%
90%
Flint (1922-23)
Edward Daseler (1947)
Nicholas (1951)
Present Study (2006)
Arterior
Posterior


Pie Chart - 2 : ORIGIN OF RIGHT HEPATIC ARTERY
5%
95%
Hepatic artery proper
Other Sources

Extra hepatic union	62.5
Intra hepatic union	37.5

	Extra hepa	Intra hepatic
Brewer (1900)	100	0
Rugg (1908)	79	21
Eisendrath (1918)	100	0
Thompson (1933)	90	10
Present Study (2006)	62.5	37.5

Flint (1922-23)	14.05%
Lurje (1937)	2.08%
Edward Daseler (1947)	1.06%
Present Study (2006)	17.05%

Coeliac right hepatic artery	92.05%
Other sources	7.05%

Hepatic artery proper	95%
Other sources	5%

Cystic artery posterior to common hepatic duct	92.05%
Cystic artery anterior to common hepatic duct	7.05%

	Anterior	Posterior
Eisendrath (1918)	27%	73%
Flint (1922-23)	16%	84%
Edward Daseler (1947)	21.02%	2%
Present Study (2006)	7.05%	92.05%

	Arterior	Posterior
Flint (1922-23)	12.05%	68%
Edward Daseler (1947)	11.06%	65%
Nicholas (1951)	12%	88%
Present Study (2006)	2.05%	90%

Hepatic artery proper	95%
Other Sources	5%